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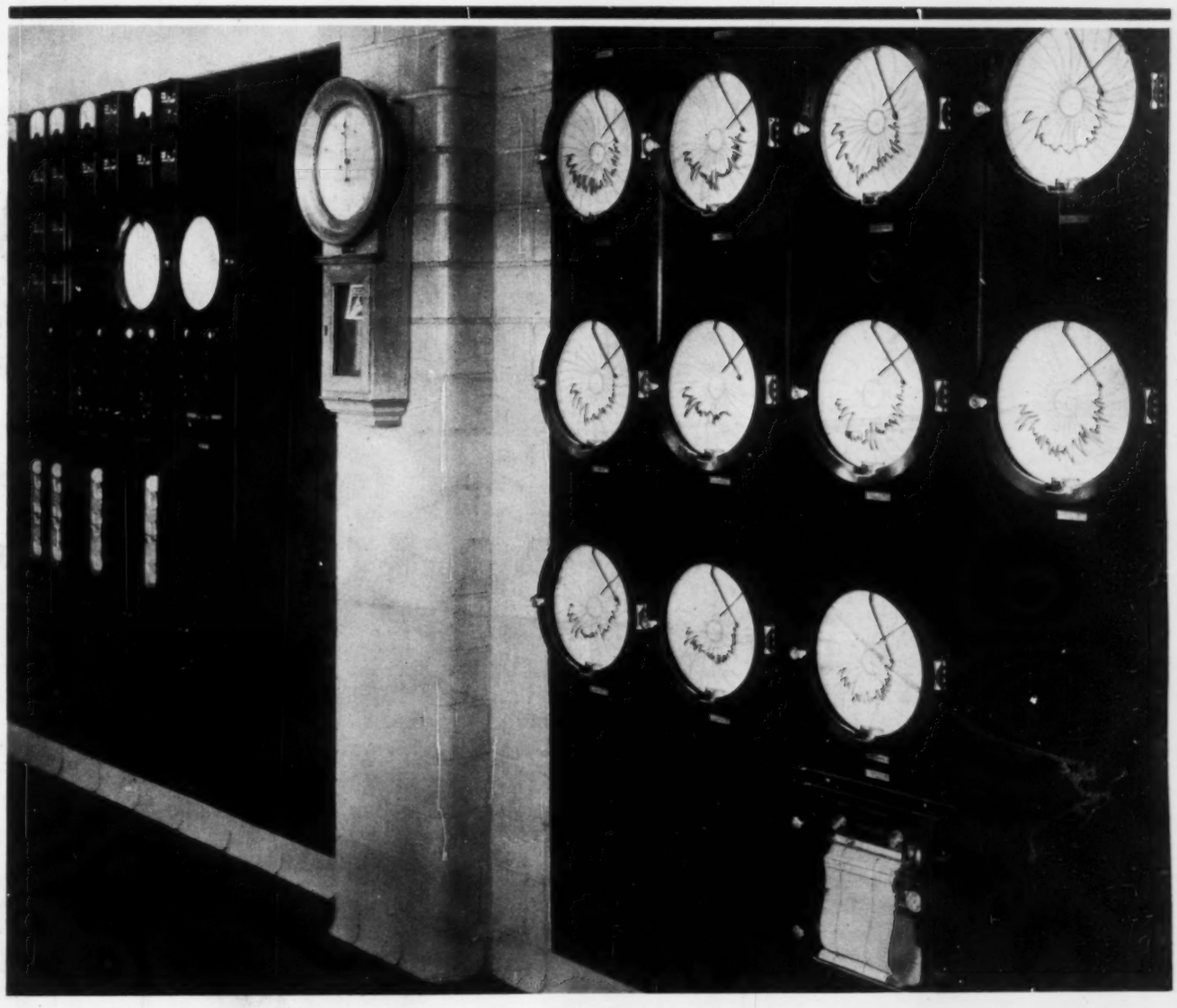
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT AND CONTROL

VOLUME 7 DECEMBER, 1934 NUMBER 12



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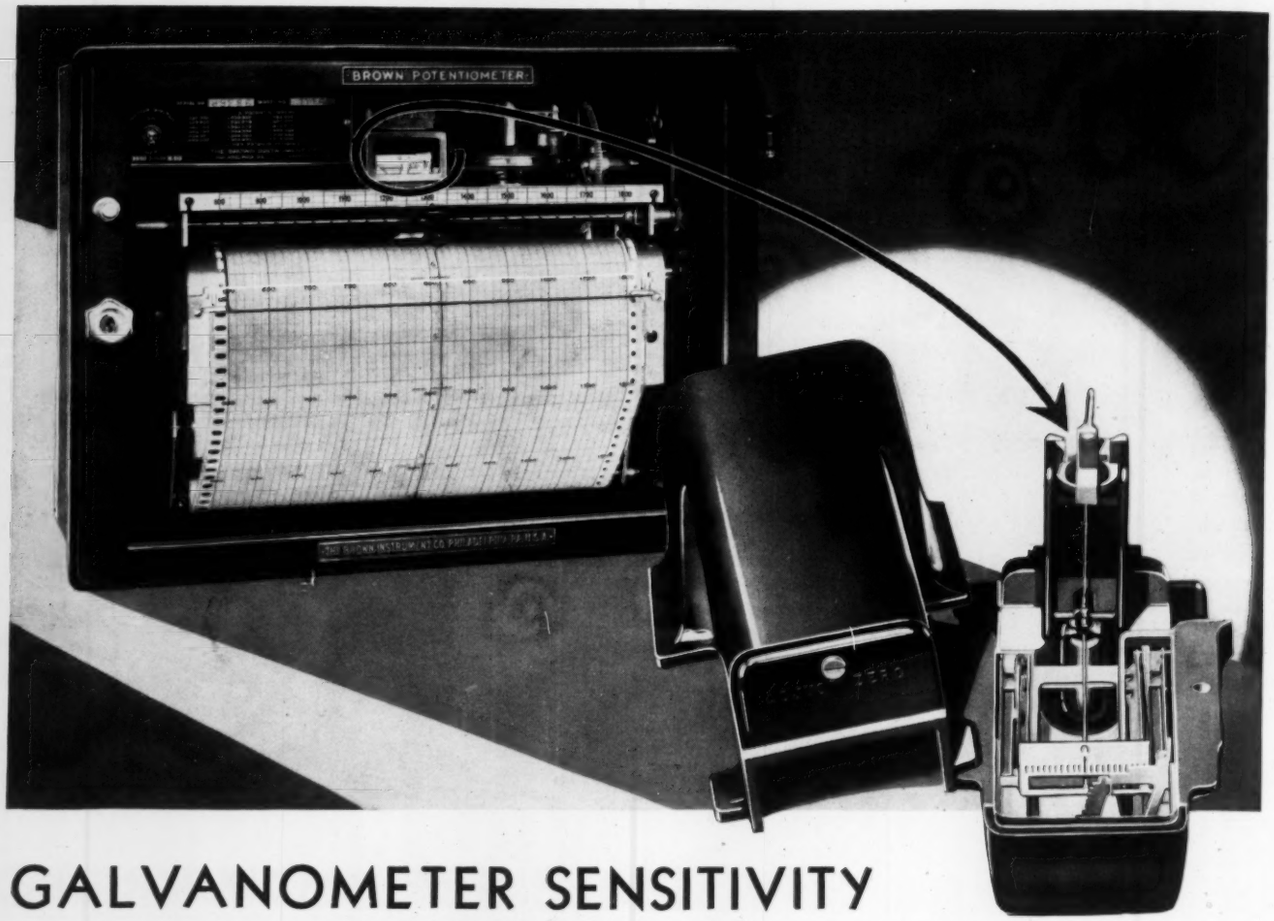

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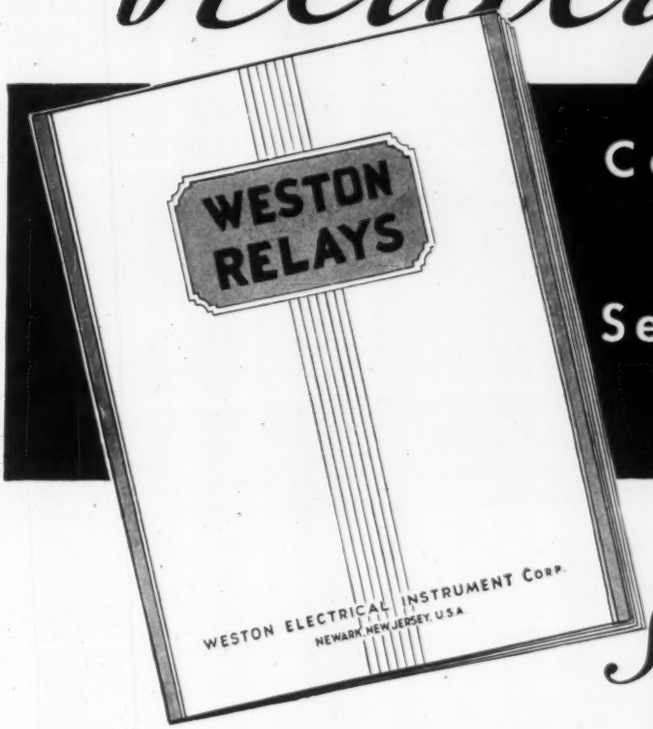

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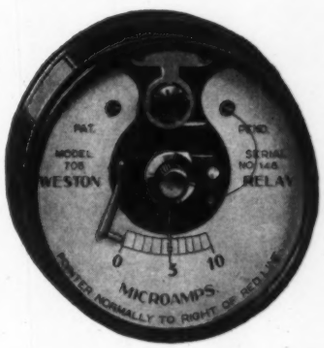

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INSTRUMENTS

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Pittsburgh, Pa.

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330 West 42nd Street
New York, N. Y.

Branch Offices
Boston: James Condon, 6 Marlboro St.
New York: Edwin F. Ripley, 330 W. 42nd St

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Published Monthly on the 15th by
The Instruments Publishing Company
JOSEPH J. VIGNEAU, President
RICHARD RIMBACH, Vice-Pres.-Treas.

Annual Subscription: U. S. $2.00. All other countries $3.00 (Remit by New York Draft to 330 West 42nd Street, New York, N. Y.)
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Entered as second-class matter January 26, 1932, at the post office at Pittsburgh, Pa., under the Act of March 3, 1879.

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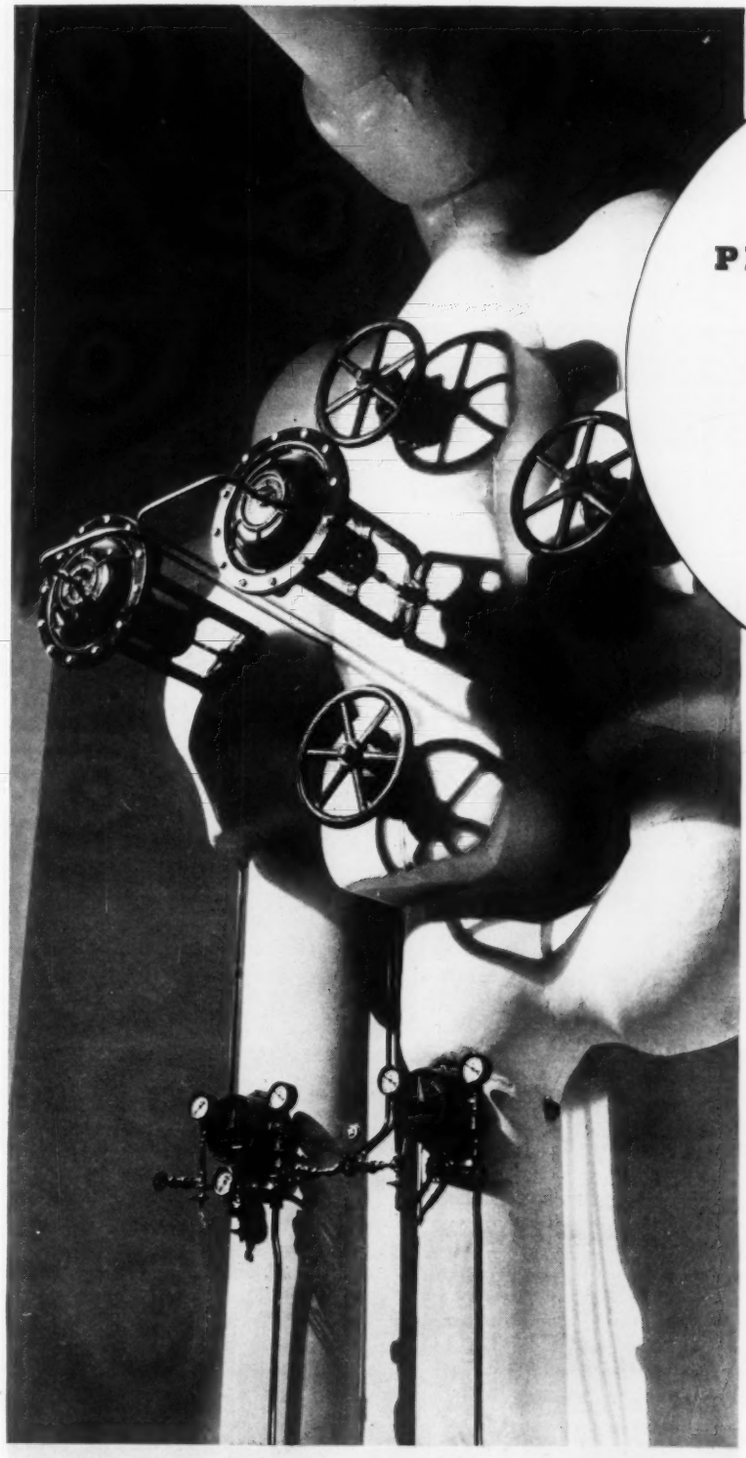

This photograph shows Taylor Instruments for cooling-liquid temperature and return pressure control. Both are installed in the refrigeration room of the Hoffman Beverage Company's brewery.

HOW CAN PLANTS BE SURE OF *exact* TEMPERATURE CONTROL ?

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EDITORIAL COMMENT

In This Issue

The technique of high vacuum demands on the part of the operator a sound knowledge of fundamentals and a high degree of skill in applying them. Knowing that many *Instruments* readers are interested in vacuum apparatus, we had been looking here and there for someone to write an article of practical value. Success! Here it is, beginning on the facing page and overflowing four pages.

It always gives *Instruments* pleasure to publish—and *Instruments* readers pleasure to read—articles describing the application of automatic control to processes and operations previously "all manual." The assorting by weight of large steel sheets was all a series of tiresome handlings until F. S. Miller made it automatic at Wheeling Steel. Thanks to the National Scale Men's Association we are able to have him tell you how he did it.

C. H. Gibbons continues his well-written history of materials testing machines. Last month, in his first installment, he traced their origin across the Atlantic. Now, he mentions the famous Philadelphia machine, and brings out the surprising fact that it is the oldest in the world in serviceable condition.

In this month's instalment of the electrical measurement series, recording instruments of direct-acting (or direct-deflection) types are taken up, after a general discussion of all electrical recorders.

Again an extraordinary variety of New Instruments.

A full page of manufacturers' new booklets (page 269).

Ditto of book reviews (page 270).

The Front Cover

In August of last year we printed an article on Modern Brewery Instrumentation wherein the processes were discussed. It seems that modern breweries take great pride also in the appearance and efficiency of their power plants. Certainly this is a fine-looking control board which the Brown Instrument Co. installed at the Theodore Hamm Brewery in St. Paul.

The Counter Reads

00084

In calling attention to the fact that *Instruments* now ends its seventh year, we make only two brief comments: (1) If it were not for the *growth* of interest in Measurement and Control, we could not have survived. (2) This growing interest indicates that although the financial structure of industry is still shaky, its foundation of enlightened striving for progress remains as solid as ever. We invite comments from both old and new readers. Are we giving you exactly what you want? What improvements (within reach, of course) would you suggest?

Defend Science and Industry!

FREEDOM of expression being a cherished American institution, there is no legal way of muzzling anti-science and anti-machine agitators. To be sure, those of us who know that research, development and technical progress in general contribute to human welfare enjoy an equal right to utter our views; but too many of us fail to exercise this right. Too many of us yield the floor to cunning prejudice-inciters. Too many of us believe that tax-payers possess enough common-sense and command enough influence to prevent the passage of anti-machine legislation.

Instruments believes that this sense of security is unfounded: in our opinion the danger of a new kind of "Prohibition" is imminent. Congress has not yet enacted measures specifically naming labor-saving devices as illegal, but an ominous start has been made by NRA officials toward limiting machine hours and opposing the purchase of modern equipment, while CWA officials all over this country are reported to have carried technophobia to absurd limits: paying hundreds of men to do the work of power shovels, crushers and conveyors which are made to stand idle while their operators (supreme irony!) are given hand shovels and hand sledges and wheelbarrows.

We have previously uttered similar warnings on this page, only to be told that the prejudice-inciters' appeals to emotions can't be fought with cold appeals to reason. Very well: even if voters in the mass are of infantile mentality they can nevertheless be swayed by *object-lessons.*

One such object lesson has just closed in New York: the Exposition of Power and Mechanical Engineering. Another is about to open in Pittsburgh: the Science Exposition at the Mellon Institute.* The one has been, and the other will be, viewed by non-technical citizens and be written up in some newspapers. The Century of Progress Exposition at Chicago is over, but all-year-round object lessons are being given at the Museum of Science and Industry in New York, at the Franklin Institute in Philadelphia and at kindred museums in several other cities.

Another way of influencing people is over the radio. The Science Service Radio Talks represent a splendid beginning. We say a beginning, for the listeners are few in comparison to those who tune in regularly on sermons—and it is a deplorable fact that some of the most popular radio preachers are poisoning the minds of simple folks with anti-science virus. We recently heard one (whom we respect highly) declare that the killing of sixty-two worshippers in the Church of St. Gervais on Good Friday 1918 by a single "Paris Gun" shell represented the highest achievement of modern science.

As for newspaper editors, most of them play up the "technological unemployment" bugaboo, delight in printing local anti-science and anti-machine talks, kill all but the sensational news items pertaining to engineering progress, and run pseudo-science features which do more harm than good.

We must not "take it on the chin and lie down." We must enlighten those who mold public opinion. No use wasting effort on prejudice-inciting racketeers. Many honest bigwigs who inveigh against technological progress, however, could be converted.

Among these bigwigs—incredible as it seems—are some manufacturers! Yes, self-satisfied industrialists who not only veto purchases of instruments and control systems in their own plants but—we are informed—beg the NRA to forbid their purchase by other plants in the industry, on the grounds of "unfair competition." Here is a chance for personal missionary work by *Instruments* readers who are itching to "do their part" in the defense of science and industry. For Instrumentation is the eugenic marriage of science and industry—in which both rejoice, and of which a higher standard of living is the first offspring.

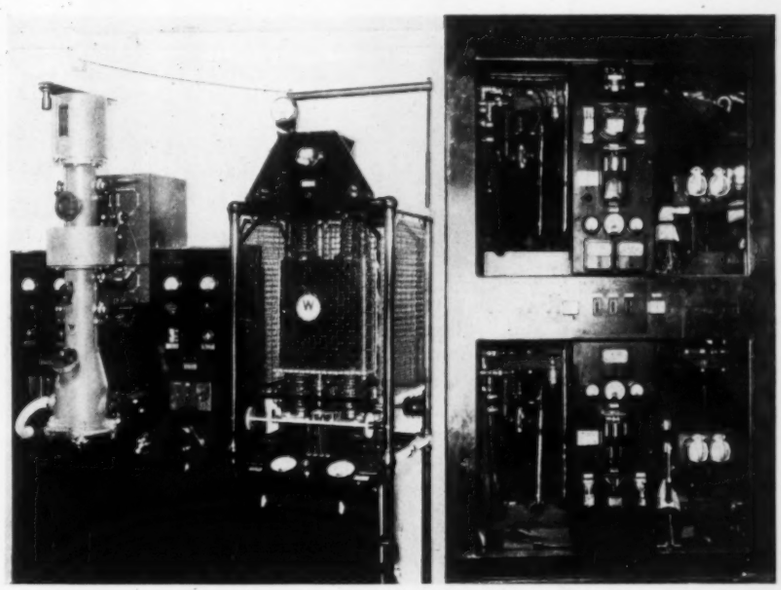
M. F. BEHAR

Instruments will occupy Booth 21.

Production and Maintenance of Vacuum in the Cathode-ray Oscillograph and Similar Apparatus

By F. R. BENEDICT*

VACUUM chambers to be evacuated are connected to pumps and low-pressure gages by hollow conductors through which the gas in the chamber is removed. These conductors may have valves, cutoffs, solid and flexible sections, a number of joints as glass-to-glass, glass-to-metal, glass-to-rubber, metal-to-metal, metal-to-rubber and a variety of cone joints and vacuum seals. Frequently, the principal vacuum chamber contains apparatus which must be adjustable from the outside of the chamber. All joints and the attached system must be kept so that the system may be readily evacuated. The working pressure of a cathode ray oscillograph is about 5 microns (5×10^{-3} mm.); the working pressure of a mercury arc rectifier is about 5 microns or less. Such pressures must be maintained over long periods of time. The pumping system must have both high capacity and high efficiency. In general, the requirements and conditions for production and maintenance of vacuum hold true for various types of vacuum apparatus which many *Instrument* readers work with.



(A) Cathode-ray Oscillograph (B) Mercury-arc Rectifier

TWO TYPES OF APPARATUS WHERE VACUUM IS IMPORTANT (Westinghouse)

Pumps

The satisfactory operation of any system requires an efficient pumping arrangement. The principle of all exhaustion pumps is the transference of gas from a low pressure space to a higher pressure space, the latter being known as the exhaust side. As this action proceeds, the low pressure side is gradually exhausted while on the exhaust side pressure is built up, unless the pump exhausts to the free atmosphere. Such pumps are governed by three factors: (*a*) back pressure; (*b*) speed of pump; and (*c*) degree of vacuum obtainable.

The back pressure is simply the pressure on the exhaust side. The speed of the pump is determined by the volume, the change in pressure over a period of pumping time, the time of the pumping interval and the final pressure obtainable by means of the pump. The simple equation for pumping speed is given by the equation

$$S = \frac{V}{t_0} \log \frac{(P_1 - p_0)}{(P_2 - p_0)}$$

where the pressure is reduced from P_1 to P_2 in time t_0 and where V is the volume of the vessel or apparatus in cc. P_1 and P_2 and p may be defined in any arbitrary units of pressure. Gaede has defined S as the pump speed in cc. per second. Theoretically, there is no limit to the final pressure, p_0 which may be attained with a mercury diffusion pump.

If $p_0 = 0$ then

$$S = \frac{V}{t_0} \log \frac{P_1}{P_2}$$

When the pump has lowered the pressure so far that the limiting value is approached, the rate of exhaustion decreases even though the speed, as defined by Gaede, remains the same.

Langmuir gives the speed of exhaustion (E) as

$$E = -\frac{V}{P}\frac{dp}{dt}$$

If the limiting pressure of the pump is p_0, the speed of exhaustion decreases as P approaches p_0 and is zero when $P = p_0$.

If the exhaust pressure rises above a certain critical value, satisfactory exhaustion ceases.

The attainable vacuum depends on full advantage being taken of the speed of the pump, so that large-bore tubing must be used. (Discussed below.)

Vacuum pumps may be divided into three general classes according to their principle of operation. They are (*a*) rotary oil pumps, (*b*) mechanical molecular pumps and (*c*) diffusion pumps.

Oil pumps are used as backing pumps for the mechanical molecular and diffusion pumps. They are designed to exhaust into the air at atmospheric pressure. The rotary oil pump is an application of an old principle of pump construction, that of a solid cylinder mounted on a shaft so as to rotate eccentrically within a larger hollow cylinder. In the Gaede design of pump, contact is maintained between the rotor and cylinder by means of one or more vanes inserted in slots in the rotor. Contact is made by centrifugal force or by springs. Fig. 1 shows a pump of this type, capable of producing a vacuum of 10^{-2} mm.

*Laboratory Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

TYPES OF VACUUM PUMPS

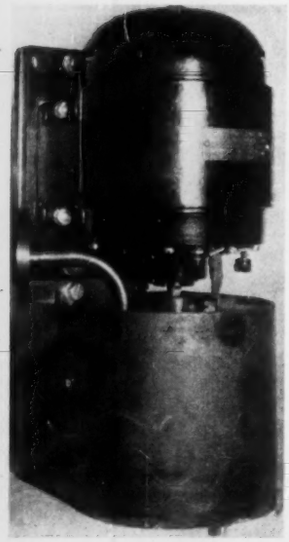
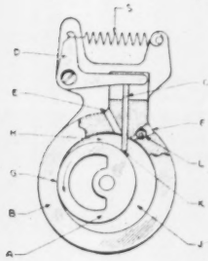


Fig. 1 Single-stage Gaede type oil pump with motor (Westinghouse).



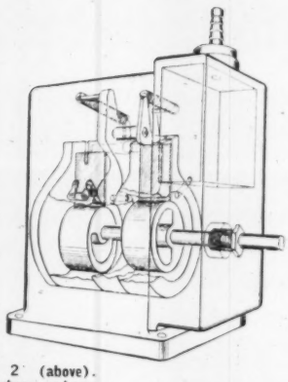


Fig. 2 (above). Double-stage rotary oil pump (Central Scientific Co.).

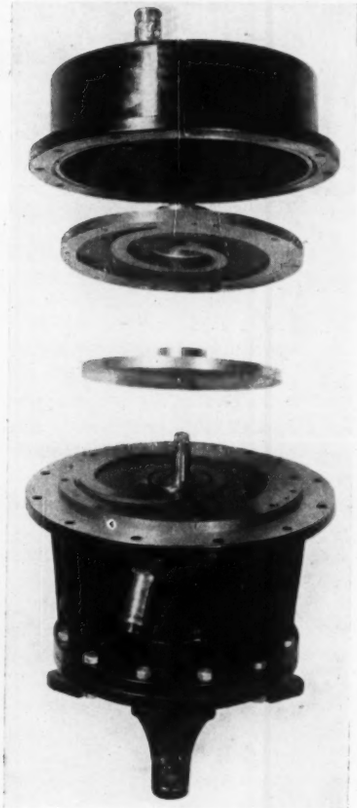
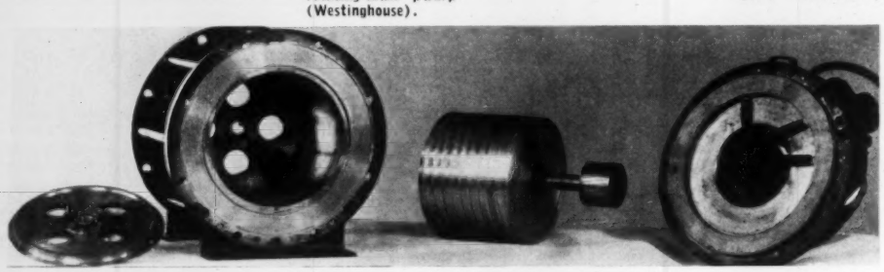


Fig. 4 (at right). Rotating-plate type (Central Scientific Co.'s "Aristovac").

Fig. 3 (below). Mechanical molecular rotating-drum pump (Westinghouse).



While the Cenco Hyvac pump, Fig. 2, employs the same principle as the Gaede pump, its vanes are mounted on the stationary cylinder. They are free to move up and down on the rotor and are placed between the low- and high-pressure points. The pump is built with two rotors, so angularly arranged on the shaft that one acts as a backing pump for the other. The rotors and cylinders are mounted in an oil bath for lubrication and sealing purposes. The pump is capable of producing a vacuum of 10^{-3} mm.* and has a capacity of 6 liters* per minute, exhausting to atmosphere.

When pressures lower than 10^{-3} mm. are desired, two pumps are placed in series. The usual arrangement for a cathode ray oscillograph system is a mechanical molecular pump in series with a rotary oil pump. Such an arrangement may be made quite compact and portable. It may be desirable to use a mercury diffusion pump instead of the mechanical molecular. The power and water required for a mercury pump make it slightly less convenient, particularly where the apparatus is to be moved occasionally.

Mechanical molecular pumps are of the rotating drum or rotating plate type. A pump of the Holweck type is shown in Fig. 3. The rotor revolves at high speed inside the large cylinder, the clearance between them is very small, 0.002 in. or less, and a continuous helical groove is cut in the rotor. Air molecules, entering the low-pressure end of the pump, acquire velocity in the direction of rotation upon striking the moving cylinder and are thus virtually driven from one end of the pump to the other along the helical groove. The pumping speed is about 1500 cc. per second at 3200 rpm. Below 2800 rpm. the pumping speed drops rapidly so the pump must be kept in good condition at all times. The mechanical molecular pump requires a fore vacuum of about 10^{-2} mm. This fore vacuum is obtained by a single- or two-stage oil pump. A tight, gas-free system may be pumped down to 10^{-7} mm. with the two pumps operating in series.

Rotating-plate mechanical molecular pumps operate on the same principle as the rotating drum type; see Fig. 4. They can be designed to have high pumping speeds, 2000 cc. per sec., and will evacuate to the same order of pressure, 10^{-7} mm., as rotating drum types.

Both the rotating drum and rotating disk pumps are subject to bearing friction. Contrary to popular opinion, the bearings may be oiled if a good, high-speed bearing oil is used. The pumps are designed so that the bearings are on the high-pressure end of the pump. Slight oil vapors at this position cause no trouble in the system as it is quite improbable that they will leak back through the molecular pump. For very low pressure work, any possible stray vapors from the pumping system can be eliminated by a liquid air trap suitably placed in the vacuum line. For low pressure work, 10^{-3} mm. to 10^{-5} mm. and lower, a *mercury diffusion pump* in series with a one-, two-, or even three-stage oil pump, is preferred. The diffusion pump may be single-, two- or three-stage, depending on the requirement of final pressure and pumping speed. Fig. 5 shows the inner parts of an all-metal three-stage mercury diffusion pump which consists of a mercury boiler, a mercury condensing system, a diffusion stage and two ejector stages. With a single-stage oil pump of the Gaede type as a backing pump, vacuum of 10^{-5} mm. is readily obtainable if the vessel or apparatus being evacuated is small, gas-free and tight. The pumping speed is from 4 to 5 liters a second under normal conditions. Most of the common mercury diffusion pumps work on the same principle and differ only in mechanical construction.

*Editor's Note. In a table of vacuum pump characteristics published by the manufacturers, we find six models of the "Hyvac" pump, the attainable vacuum of all being given as 4×10^{-4} mm., and their capacities ranging from 8.9 to 10.4 liters per minute.

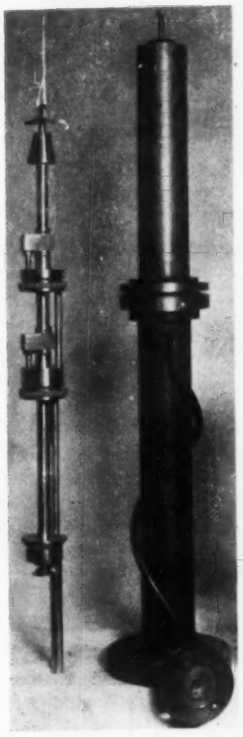


Fig. 5. Inner parts of three-stage all-metal mercury diffusion pump (Westinghouse).

Vacuum Gages

If a pumping system has been chosen for a particular vacuum application, it is desirable to measure the pressure at many or all stages of an evacuation process. Four of the common methods available for measuring low pressures are: (*a*) the glow discharge gage, (*b*) the McLeod gage, (*c*) the Pirani gage and (*d*) the ionization gage.

The *glow discharge gage* is simply a glass tube, sealed to the system, in which a cathode and anode have been placed. If high voltage d-c. or interrupted d-c. is placed between the cathode and anode, the character of the discharge will change as the pressure is reduced. The character of the discharge may be calibrated quite accurately against pressure (see reference 4).

Cathode ray oscillograph vacuum can be judged at any time without trouble because the cathode tube, an integral part of the instrument, is a form of glow discharge tube. This type of gage fails at about 2 microns, as the gas at this pressure almost totally ceases to conduct, even with thousands of volts between the cathode and anode.

The *McLeod gage* employs the "compression manometer" principle and hence is a "primary" instrument in the sense that it is possible to construct and calibrate one without reference to another pressure instrument. It finds application in almost every line of vacuum work and, if operated correctly, is capable of high accuracy. Fig. 6 shows the Cenco design of McLeod gage for high vacua. Fig. 7 shows a McLeod gage constructed for rectifier work. It is of the improved Gaede type in which the mercury column is eliminated by evacuating above the mercury pool, and is designed for measurements down to 10^{-3} mm. It is possible to estimate the pressure to 10^{-4} mm. By proper proportioning of the capillary tube and bulb volume, the gage can be designed to measure pressures to 10^{-5} mm. Pressures of 10^{-6} mm. can be estimated. For low pressures it is absolutely essential that the air admitted to the McLeod gage be dry and free of condensible vapors, particularly water vapor. The mercury must be kept very pure and free of contamination at all times, as the capillary tube fouls easily.

The *Pirani gage* employs an electrically heated filament, enclosed in a glass bulb which is connected to the vacuum being measured. The presence of gases in the bulb affects the rate at which heat is lost by the filament, and hence its temperature. The temperature change is measured by using this filament as one arm of a Wheatstone bridge circuit and—as the conjugate arm—the filament of a similar bulb evacuated to the approximate pressure which is to be measured and sealed off permanently. The sealed-off bulb serves as a reference or comparison bulb. A set of Pirani gage bulbs is shown in Fig. 8. The instrument panels of two Pirani gages employed for automatic control of mercury arc rectifier vacuum may be seen in Fig. B. The pressure changes are obtained from readings of the unbalanced bridge current which flows through a sensitive galvanometer. Each gage is arranged with a relay to de-energize the rectifier in case the pressure becomes too high.

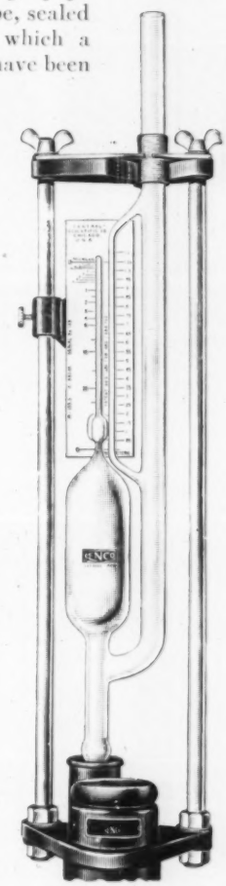


Fig. 6. Upper portion of a 5x10 $^{-6}$ mm. McLeod gage (Central Scientific Co.).

The Pirani gage, being sensitive to gas composition, must be calibrated for the gas used. If the gage is used on apparatus where the gas may be ionized or excited, the gage may be in error as much as 5 microns. The excited atoms bring extra energy to the filaments, and raise the temperature, which gives the same effect as a lower pressure. The gage may be used to measure pressure changes down to 10^{-5} mm. The chief advantage is that it may be made continuous direct-reading, which is desirable in rectifier work. It is equally applicable to other types of vacuum work where continuous pressure readings are of value.

For measurement of very low pressures, 10^{-5} to 10^{-8} mm., some form of *ionization gage* is necessary. A large proportion of these gages are of the three-electrode (filament, grid, plate) type. It has been found that if the gas in the gage tube is not sufficient to affect the filament activity and the plate voltage exceeds the ionization voltage, the number of ions formed is proportional to the gas pressure and to the electron current passing through the gas from cathode to anode. The relation of positive ion current against pressure is linear down to pressures as low as 10^{-8} mm. The gage must be calibrated with the gas whose pressure is to be measured. A knowledge of the gas is necessary for correct use. This gage is strictly a research instrument and requires an apprenticeship to obtain consistent and satisfactory pressure readings. Fig. 9 shows a vacuum gage of this type.

Fig. 7. A special McLeod gage for rectifier work (Westinghouse).

Testing for Leaks

Vacuum troubles in a system may appear without warning. Much time is lost if a proper procedure for locating the trouble is not followed through. Inability to obtain vacuum may be due to three main causes: (*a*) a leak in the vacuum system, (*b*) loss of pumping efficiency and (*c*) gas produced within the vacuum

system. The amount of leak may be visually tested with a glow discharge gage or a McLeod gage. The leak is checked with the pumps sealed off from the system. If the leak is in the vacuum system and not in the pumps, the system is sectionalized and shutoffs placed at the section points. The system is then shut off at these points in consecutive order. This sectionalizing process will usually locate the general position of the most stubborn leak. Sectionalized leaks are best located by using the glow discharge tube as a vacuum indicator: a swab of cotton, saturated with alcohol, ether or other liquid is applied to the suspected place on the outside of the chamber. The vapor from the liquid will be drawn into the chamber through the leak and its presence will immediately be revealed by the changed color of the discharge.

Metal vacuum chambers may also be tested for leaks by immersing them in water and applying air pressure. Small leaks show up immediately. Leaks in glass tubing systems are easily tested with a high voltage spark coil: one electrode is sealed into the system and the other is used to explore at joints and along the tubing. If the exploring electrode strikes a leak, the system glows inside. Leaks many feet from the sealed-in electrode may be located in this way.

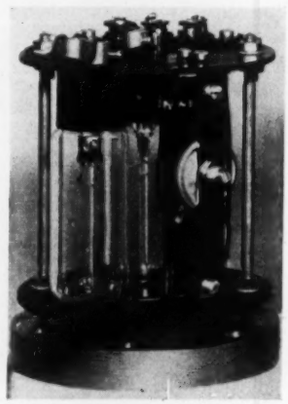


Fig. 8. Pirani gage bulbs—cover removed (Westinghouse).

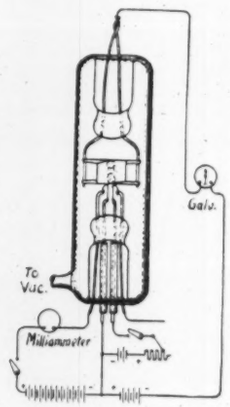


Fig. 9. Ionization gage—Found's design (Dushman).

Care of Pumps

If vacuum cannot be obtained on a tight system the pumps should be examined carefully. Bearing friction may cause a mechanical rotating-drum molecular pump to run slow. For most pumps of this type the drum should rotate about 3200 rpm. in air. If the speed is below 2800 rpm. in air, the pump should be serviced and bearings replaced. Oil pumps seldom cause trouble unless they are old and have worn parts. Under normal operating conditions the oil should be changed about once a year. If the pump is used to pump corrosive vapors, the oil should be changed oftener because of vapor absorption in the oil.

Mercury diffusion pumps are quite trouble-free provided that the mercury level is maintained, that mercury boiler temperature is sufficient, that condenser water is sufficient and that the backing pressure is normal.

Large-bore Tubing Essential

Pump efficiency is often blamed for long pumping times. The trouble, in many cases, can be traced directly to the size of the tubing connecting the vacuum chamber to the pumps. The effective speed of a pump, especially one of the mercury diffusion type, should not be reduced more than 25% by connection of tubing. To make this possible with such pumps, the ratio of $\frac{D^3}{L}$ or $\frac{\text{Diameter}^3}{\text{Length}}$ should be about 4. For a tube 40 cm. long the bore D should be 5.42 cm. For long lengths of tubing the bore must be very large if high efficiency is desired. Efficiency is often sacrificed and small tubing used in order to locate conveniently the component parts of vacuum apparatus and to conserve space. The pumping time is thereby increased, often many times over that which should be required. While there is no theoretical limit to the lowest pressures obtained by certain pumps, in practice the limit of pressure is determined by the bore of any connecting tubing. If the tubing is of small diameter and low pressures are desired, pumping time can always be shortened by using larger tubing.

"Gassy" Systems

Vacuum chambers which are being pumped out for the first time usually gas copiously. The gas is absorbed or adsorbed by parts within the chamber. Some chambers must be pumped for days before all the adsorbed gas is pumped out. Gas may also be produced by fluids which have been used to clean the chamber or parts within the chamber. If it is possible, no liquids of any sort should be used inside the chamber. If any must be used, ether is preferable. Benzine should never be used and carbon tetrachloride on high-pressure sections only. Cleaning fluids should never be touched to hard rubber, micarta, mica or any absorptive substance within the vacuum chamber. Should such parts gas, they should be heat-treated under vacuum. Repeated airing often helps to get rid of gases which have been adsorbed or absorbed.

Gas in a cathode ray oscillograph may make it totally inoperative. The most common gas encountered is water vapor from the rolled photographic films. Before using, these films should be dried in vacuum in the presence of phosphorus pentoxide (P_2O_5) for several hours before use in the oscillograph. Occasionally even one that has been dried will gas for some time after being placed in the oscillograph. Intermittent pumping and airing will usually eliminate the trouble. Plenty of drying agent should be used in the oscillograph at all times. It is cheap in comparison to the value of the time wasted by sparing it.

Phosphorus pentoxide (P_2O_5) cannot be used as a drying agent on many vacuum systems as the phosphoric acid that results when pentoxide dissolves in its adsorbed moisture diffuses slightly throughout the volume and may attack metal parts and cause corrosion of any exposed metal surfaces. This corrosion in the cathode ray oscillograph has not been found objectionable. It is reduced to a negligible factor by lacquering metal parts which are not bombarded by the electron beam. Phosphorus is preferred in oscillography as it absorbs very rapidly and does not coat over and lose its active surface.

Other drying agents such as activated alumina, silica gel and activated charcoal are used on vacuum systems where contamination of walls cannot be tolerated. All of these substances may be regenerated by heating and used many times. For low-pressure work, liquid air freeze-out traps are helpful for eliminating condensible vapors.

Metal vacuum systems, whose parts are subject to bombardment by ionized atoms, must be prepared with special care. Absolute cleanliness is essential. Cotton gloves should be worn at all times to keep perspiration and moisture on the hands from touching any internal parts. Oil is a particular foe of high vacuum as it gasses voluminously on bombardment. All parts which may be slightly porous should be heat-treated in vacuum to get

(Continued on page 256)

Automatic Sheet Assorting by Weight

By F. S. MILLER*

IN the manufacture of sheets and tin plate the mills are unable to roll uniform gages. As all sheets and tin plate are sold on base weights, it is necessary to weigh the individual sheets either by the slow method of weighing each sheet on a scale by hand or by employing women to estimate the weight by picking up each sheet. The first method is too slow and costly, and the second (while faster) is not as accurate as desired by the manufacturer. In order to obtain both speed and accuracy we have developed, constructed and patented an automatic sheet assorting machine for assorting tin plate sheets varying from 14″ wide by 20″ long to 30″ wide by 40″ long, in gages ranging from 24 to 38.

This machine is capable of assorting sheets into three weights—light, medium and heavy, the medium sheet being the required base weight, at an average rate of 1500 per hour for sheets 30″ x 40″ (or 12 base boxes) to 1800 per hour for sheets 14″ x 20″ (or 16 base boxes). The machine has been in continuous production day and night since December 1931 with the exception of holidays and has assorted 29,000,000 sheets up to May 1, 1934, at a negligible cost of replacement of parts.

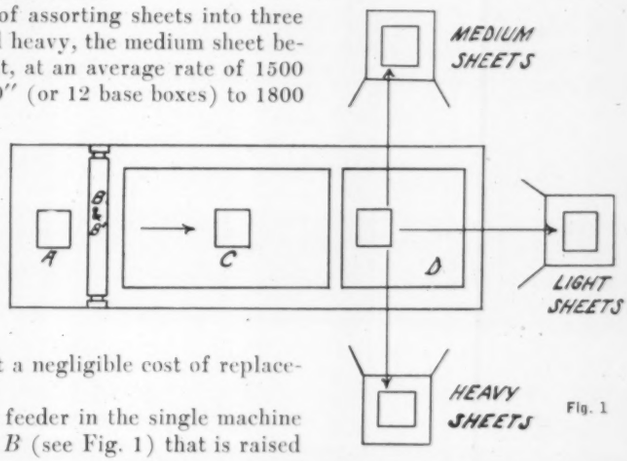


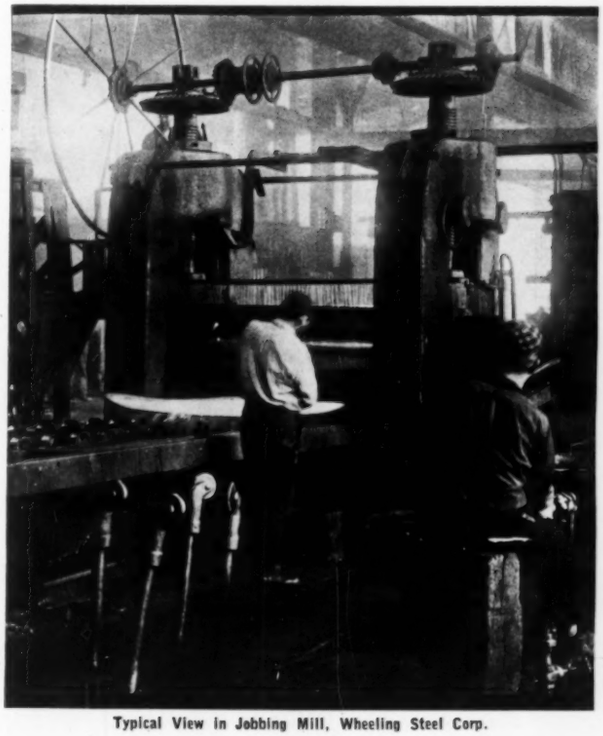
Fig. 1

Feeding Mechanism. The feeder in the single machine is composed of a feed roller *B* (see Fig. 1) that is raised and lowered by a variable-speed motor and feeds the sheets at the correct speed, depending upon the size sheets being weighed, upon a constant speed belt conveyor *C* which, in turn, delivers the sheets on to the scale table *D* of the weighing mechanism.

The feeder in the duplex machine (Figs. 2 and 3) consists of a Dexter feeder *A* with a lifting and lowering conveyor, driven by a variable-speed motor, which feeds the sheets at the correct speed upon upper and lower constant-speed belt conveyors *C* and *C′* which, in turn, deliver the sheets on the upper and lower scale tables *D* and *D′* of the weighing mechanism.

Weighing Mechanism. The weighing mechanism consists of a standard scales with an inverted pointer upon which is mounted in the place where articles are usually weighed, a scale table the belts of which are driven by a constant-speed motor attached to the scale table. The scales are mounted upon a stationary base. The movable make and break contacts *E*, *F* and *G* mounted on the scale levers *I* of the scales, make contact with the three stationary contacts mounted on the stationary base and close the electric circuit to one of the three magnets, depend-

*Chief Scale Inspector, The Wheeling Steel Company.
Presented at the National Scale Men's Association Convention, Chicago, June 12-13-14, 1934.


Typical View in Jobbing Mill, Wheeling Steel Corp.

Typical View in Sheet Mill, Wheeling Steel Corp.

ing upon whether the sheet is a light, medium or heavy one. The three stationary electric contacts, which require close adjustment in order to get accurate weights, are raised and lowered by means of a small hand-operated gear reducing unit located on the stationary base. The scales have an inverted pointer permitting the operator to check the performance of the machine.

Discharge Mechanism. The discharge mechanism consists of three steel rollers *K-1* rotating in a left hand direction, three steel rollers *J-1* rotating in a forward direction and three steel rollers *L-1* rotating in a right hand direction, mounted one inch above the scale table belts and driven by one constant speed motor *G*. Mounted directly above each set of three steel rollers are magnets *K*, *J* and *L* whose circuit is actuated by electric contacts *E*, *F* and *G* on the scale levers and photoelectric relay *H*. Ball bearings are used throughout the machine. All the machinery is carried on one rigid structural steel framework, thus making it portable. Each one of the three motors *P*, *Q* and *R* have their own separate switch and starter and a separate switch feeds the three magnets. An indicating lamp is mounted on top of the discharge mechanism which lights each time a magnet is energized.

High Finish Sheet Storage
Wheeling Steel Corporation

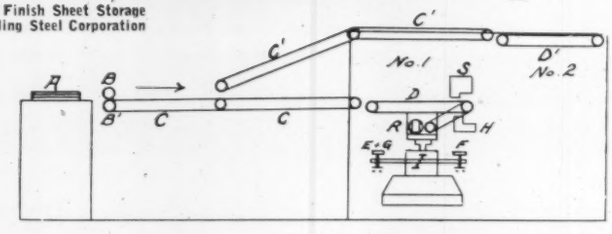


Fig. 2

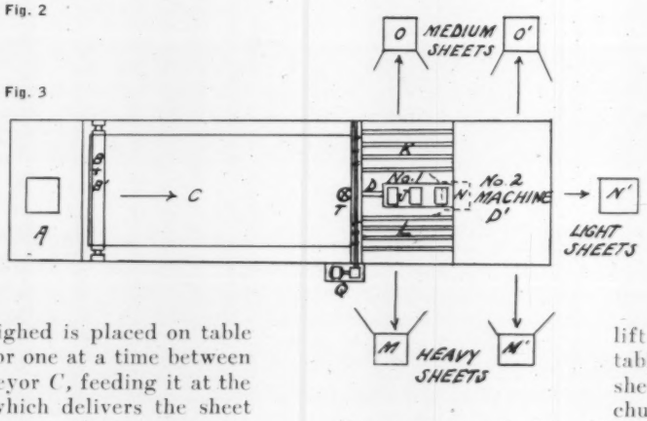


Fig. 3

Operation

When a single machine is used the pile of sheets to be weighed is placed on table *A* (Fig. 1) and fed by an operator one at a time between feed roll *B* and roll *B-1* of conveyor *C*, feeding it at the proper rate upon conveyor *C*, which delivers the sheet upon the running scale table *D*.

The scales are set to a predetermined weight so that the correct weight sheet will bring the scale pointer to the zero mark. If the tolerance on the sheet is, say two ounces minus and plus, the light and heavy contacts are adjusted to operate when the weight differs from that amount. When the sheet is delivered upon the running scale table *D* its weight begins to move the scale lever *I* (Fig. 2). If the sheet is a light weight one, weighing less than the two-ounce tolerance, scale lever *I* moves automatically only enough to cause the light weight contacts *E* to close the circuit to the middle or light weight magnet *J*. In series with this contact *E* is photoelectric relay *H* which operates, when the sheet intercepts its light source *S*, completing the circuit to the magnet, causing it to magnetize the rotating rolls *J-1* (Fig. 3) which lifts the sheets from the scale table *D* (Fig. 2) and discharges the sheet forward into a chute or piler *N* (Fig. 1), thus allowing scale table *D* to return to its off position ready for the next sheet.

When a magnet is energized the lamp *T* (Fig. 3) lights, showing the operator that the magnet has functioned and, by looking in the mirror at the pointer, he can see if it has functioned correctly.

If the next sheet is a medium one its weight moves balancing lever *I*, causing it to first close the light weight contact *E* but, as the sheet has not intercepted the light source *S* of photoelectric relay *H*, the light magnet *J* is not energized, the scale lever continuing to move next causes the medium contact *G* to close and, if it is closed when the sheet intercepts the light *S* of photoelectric relay *H* causing it to close, the medium or left hand magnet *K* is energized, which magnetizes the three left hand rotating rollers *K-1* which lift the sheet from the running scale table *D* and discharge the sheet to the left into a chute or piler *O*.

If the next sheet is a heavy one, weighing more than the tolerance required, it will move the balancing lever *I*, closing both the light contact *E* and medium contact *G*, but as the sheet has not intercepted the light source *S* of photoelectric relay *H*, the circuit is not completed and the light and medium magnets are not energized. The scale lever continuing to move, next cause the heavy contact *F* to close, and if it is closed when the sheet intercepts light source *S* (causing photoelectric relay *H* to close) it will complete the circuit to the heavy, or right hand magnet *L*, causing it to magnetize the three right hand rotating rollers *L-1* which lift the sheet from the scale table *D* and discharge the sheet to the right onto a chute or piler *M*.

The contacts *E*, *F* and *G* are interlocked so that when any one is closed the circuit is opened on the other two, thus preventing more than one magnet being energized at one time.

We now have duplex machines in operation (since October 1933), that have a capacity of 3400 sheets per hour, operated by one operator.

Announcing

INSPECTION and TESTING

A MAGAZINE WITHIN A MAGAZINE

BEGINNING with the January 1935 issue of *Instruments* a section will be regularly devoted each month to the subjects of inspection and testing.

Materials Testing Machines

An Account of Their Development, with Special Reference to the Tension-Compression-Transverse Group

By C. H. GIBBONS*

PART TWO

Early in 1817 George Rennie (1791-1866), son of the elder John Rennie (1761-1821), built a testing machine essentially the same as that of Gauthey (Fig. 3) and that of Perronet (Figs. 6 and 7), having an iron lever of 10 feet length with a hardened steel insert at the point of application of the load to the specimen, and having a pin in the lever for a fulcrum. This machine had a ratio of 24 to 1, and while its capacity is unknown, the tabulated test results show loads up to 25,000 pounds.[28] Specimens were 6 inches long and 1/4" square.

Rennie also built a torsion testing machine having a 24" wrought iron lever with quadrant and a maximum torsion loading of about 500 inch-pounds.

About 1825 Lagerhjelm, for the School of Mines, Stockholm, conducted experiments on a 7-ton horizontal machine[29] which employed an hydraulic ram for load production and for absorption of the strain, and measured loads by weights on a lever having a right angle bend, the short arm being vertical and the long arm horizontal. Basically, the construction was that of the Woolwich machine and that of Kirkaldy at The Grove, Southwark Street, London, S.E., both of which are to be described later in this account.

An early testing machine of large capacity was the 130-ton (291,200 lb.) vertical at the Cyfarthfa Iron Works, Merthyr Tydvil, Wales, which was built to the designs of the Works Engineer, Mr. William Williams (Fig. 9). It was put into service in 1829 and was used for testing riveted joints; lap, single and double butt, and for testing 2" square iron bolts, some of which showed the unusual breaking stress of 30 tons (67,200 lbs.) per square inch. J. H. Wicksteed, of Leeds, Past President, Institution Mechanical Engineers, says (1906) of this machine that it was "the very first testing machine ever constructed to combine the same essential principles as the most approved and modern machines; namely, hydraulic power for strain in the specimen and dead weights acting through levers with knife edge fulcra for measuring the load."[27]

*Baldwin-Southwark Corp., Philadelphia, Pa.

28 *Transactions, Royal Society*, 1818, part 1. *Philosophical Magazine*, Vol. 53, 1819, page 161.

29 Described in *Jernkontorets Annaler*, 1826.

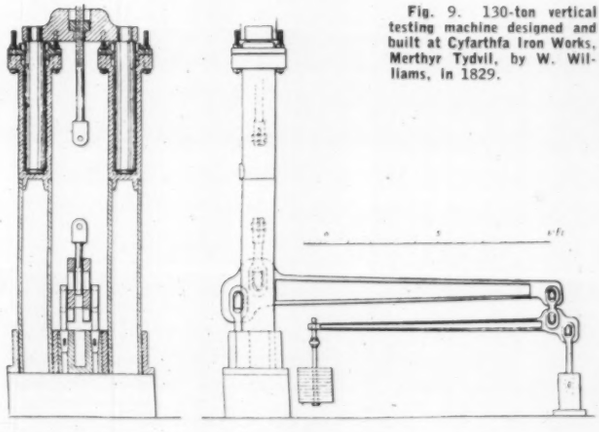


Fig. 9. 130-ton vertical testing machine designed and built at Cyfarthfa Iron Works, Merthyr Tydvil, by W. Williams, in 1829.

A remarkable series of experiments by a sub-committee of the Committee of the Franklin Institute of Pennsylvania on the Explosions of Boilers (at the request of the Treasury Department of the United States) was carried out between 1832 and 1837. It was necessary that a testing machine be built—one of the first, if not the very first to be made in America.* This machine is shown by Fig. 10. While its capacity was not stated, the maximum recorded load (from the tabulations) was 21,000 lbs., the lever ratio being 30 to 1. It was constructed of heavy oak timbers and had a working space of 60" long by 14 1/2" wide. Load was applied by adding weights to the scale pan. The screw was used, generally, only for counteracting strain.

The fulcrums of the lever were not knife edges and it was, therefore, necessary to correct for friction. After very careful experiments it was found that it was necessary to apply 5% of the observed load to friction, so that in all cases 95% of the observed load was taken as the actual load.

In all, hundreds of tests on cast iron, wrought iron, copper and cast steel were made with the greatest of care. Investigations as to the effect of temperature on the tensile strength of metals were carried out with a care and with an ingenuity which is surprising. Temperatures up to 1,317° F. were used, the specimens being immersed in molten tin.

No less remarkable were the methods of measuring temperature. Mercury thermometers were used up to its boiling point, about 675° F. Above this temperature an ingenious steam-pyrometer was employed. This instrument was based on the principle that a body of known weight and specific heat will evaporate from a body of water already in ebullition an additional quantity of water vapor proportional to its own temperature drop (to 212° F.). This body was placed in the molten tin bath, removed to the steam pyrometer, and the vapor evolved was weighed on a very carefully made balance so graduated as to read directly in degrees Fahrenheit.

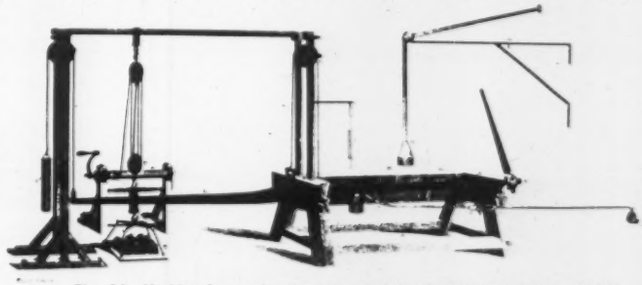


Fig. 10. Machine for proving tenacity, used by Franklin Institute in 1832.

The use of this pyrometer, of course, required that a definite knowledge of the specific heat of the body and the latent heat of water vapor be known. Elaborate and extensive tests were made to determine these factors.

For the measurement of strain, tests were made to determine the elasticity of the frame and parts of the machine itself. Correction was then made on the test results,

*This machine is intact and in serviceable condition in the museum of the Franklin Institute, Philadelphia. It is probably the oldest testing machine in the world to-day.

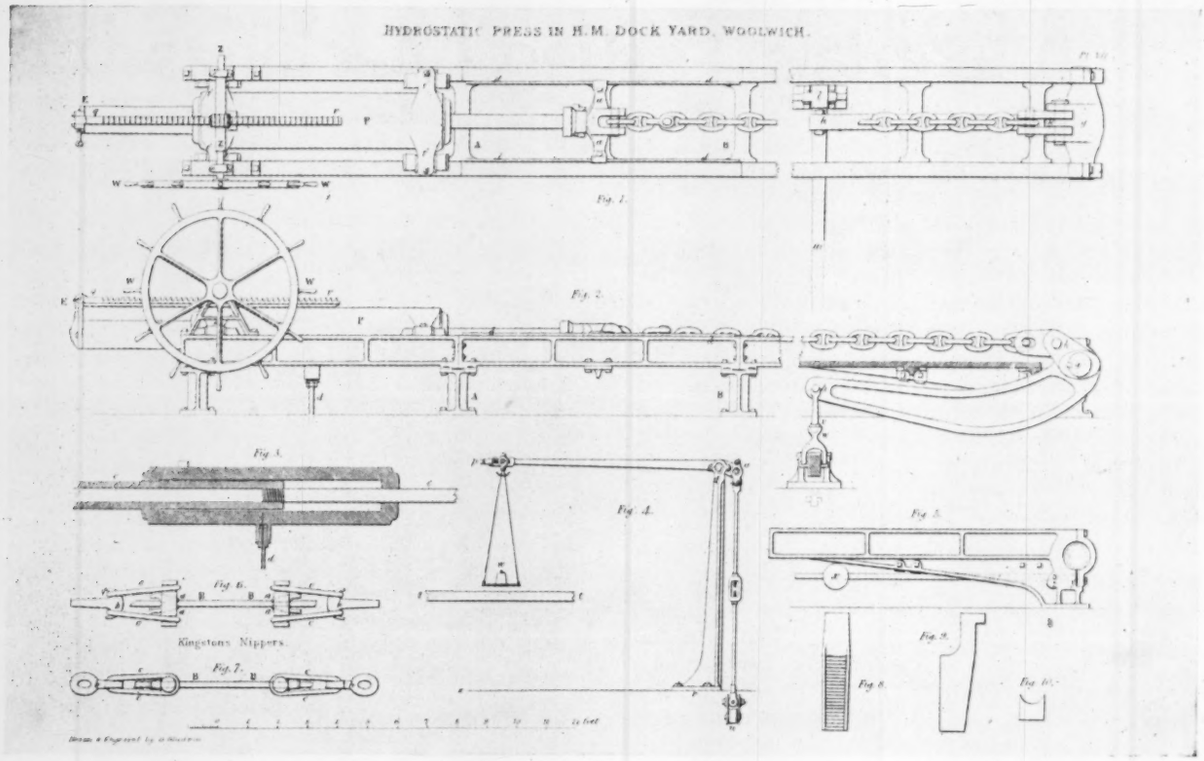


Fig. 11. The famous 100-ton Woolwich testing machine of 1833.

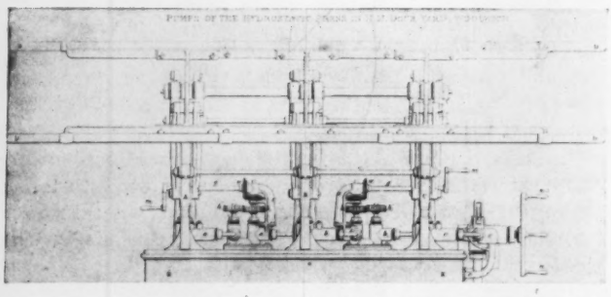


Fig. 12. Pumps used for pressure supply to 100-ton Woolwich testing machine shown in Fig. 11.

which were measured by the deviation of the index of the lever from a zero position. Since the point of the stylus was 123″ from the fulcrum and the length of the short arm was 2.914″, there was a multiplication of strain of about 40 times, and a strain of about 0.001″ could be measured. In addition, an ingenious proportional divider with vernier scale permitted reading distances to about 0.001″.[30]

In 1832 the famous 100-ton (224,000 lbs.) Woolwich Testing Machine was constructed by Messrs. Bramah, of Pimlico, London.[25] This machine is shown in Fig. 11, and was put into service in 1833. It had two side rails of cast iron, cast in 9½-foot sections and was 104½ ft. overall. It was built primarily for chain cable testing and was, therefore, narrow, being about 31″ between side rails. The piston was of two diameters, 10½″ and 5¼″, and leather packings were used. The piston was returned to initial position by rack, pinion and wheel, which are clearly shown. The lever weighing system having a ratio of 2,240 to 1, had three levers and was designed so that one pound in the scale pan produced 1 ton (2,240 lbs.) load on the chain. Attention is particularly drawn to the ingenious method of supporting the weight of the first "great lever." Two auxiliary levers with knife edges, one near each end of the hub of the great lever, bore on its underside under the action of weights at the opposite ends of the levers of which the knife edges formed a part. The idea was probably not new, as it appears also in the American machine of Fig.

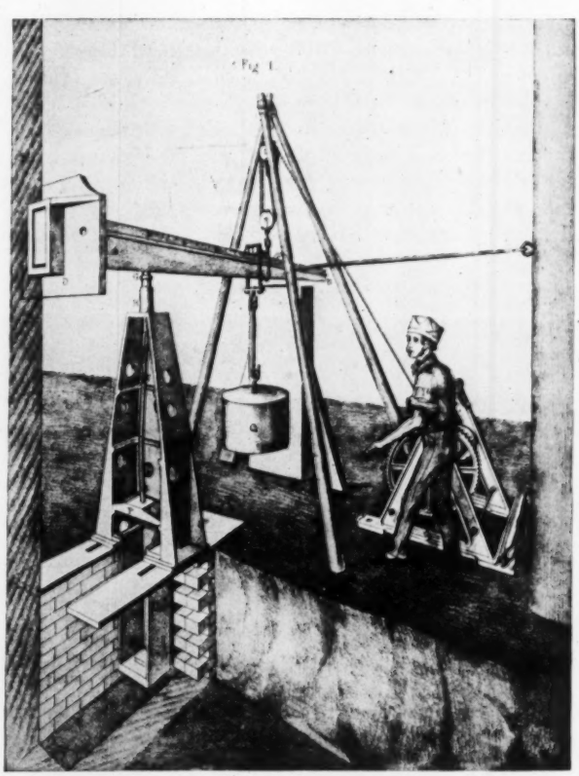


Fig. 13. The 22½-Ton Testing Machine of Eaton Hodgkinson, 1838.

[30] *Journal Franklin Institute*, Second Series, Nos. 19 and 20, 1837.

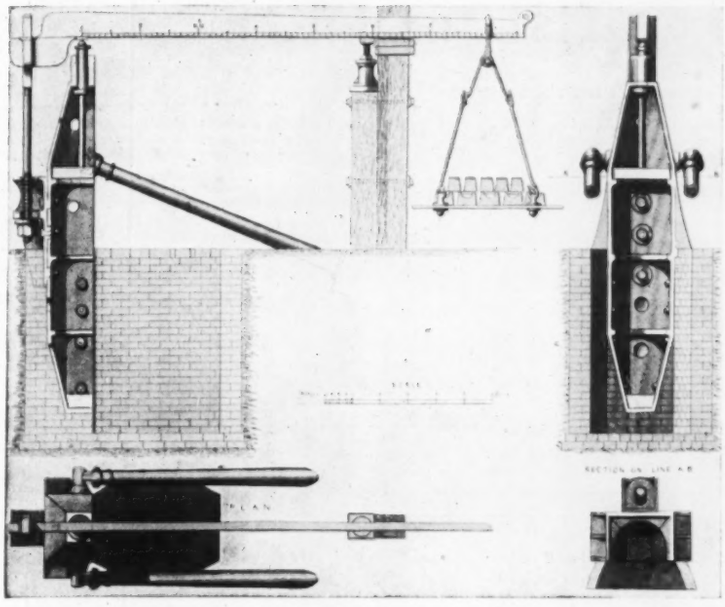


Fig. 14. Apparatus used in Hodgkinson's experiments on the strength of pillars.

10. Because of the difficulty of accurate determination and maintenance of lever arm length, the scale pan itself was adjustable. Calibration was effected periodically by a known dead weight of four tons which could be applied to the weighing system. The sensitivity of this machine is worthy of note as a weight of two ounces in the scale pan sensibly affected the balance, even when weighing near to capacity. Conversely, 280 pounds load sensibly affected the balance.

It is worthy of note in passing that this machine also had a "valve"[23, 25] for indicating the hydraulic pressure in the cylinder, but "this serves only to show the great defect of such apparatus; for while the lever scale is, as above stated, sensible to 280 lbs. ($\frac{1}{8}$ ton), the other was scarcely moved with a change of 4,480 lbs. (two tons), its indications being less and less sensible as the strain becomes greater and greater."[25]

Hydraulic pressure was applied by an ingenious pump having six plungers, two each, respectively $1\frac{1}{4}$", 1" and $\frac{3}{4}$" in diameter, and having means of rendering, first the $1\frac{1}{4}$", then both the $1\frac{1}{4}$" and the 1" plungers inoperative. All the power, therefore, was concentrated on two $\frac{3}{4}$" plungers which at full load developed nearly 3,500 lbs./in.^{2} pressure. The pump was operated by hand and was, essentially, one of the ancient fire-engine pumps (Fig. 12).

This machine was used by Peter Barlow in 1835 for his famous experiments on the strength of malleable iron for rails for railroads.[31]

About 1838 Eaton Hodgkinson (1789-1861) constructed a lever type testing machine of a maximum capacity of $22\frac{1}{2}$ tons (50,400 lbs.) (Fig. 13). This machine was adapted for compression only and was of the single lever type, the lever being about 14 feet long. There was no provision for strain compensation. The lever ratio was variable from about 4 to 1, to 7 to 1, while the maximum ordinary length of specimen was 60 inches. It was possible to accept somewhat longer specimens by extending the support into a pit below floor level. On this machine Hodgkinson carried out the famous tests on columns on which he reported in Philosophical Transactions of the Royal Society, 1840.

[31]Peter Barlow. Experiments on Transverse Strength and Other Properties of Malleable Iron, etc. London, 1835, page 22.

Because of the limitations of the early Hodgkinson machine—particularly as to column length and as to capacity—he, sometime before 1857, constructed another (Fig. 14) whose capacity is not known, but on which tests up to 136,000 lbs. load were made. It was also of the single lever type, having a lever of 17′ 6″ in length, and a lever ratio of 8.4 to 1. It accepted columns up to 120 inches in length and strain compensation was effected by a nut and screw. It was located at University College, London, and the column tests made on it by Hodgkinson are reported in the Philosophical Transactions of the Royal Society, 1857.

Prior to 1850, Sir William Fairbairn (1789-1874),[32] owner of a shipbuilding works at Mill Wall, Poplar, London, constructed a single lever tension testing machine (Fig. 15) having a capacity of about 38,000 lbs., an 8 to 1 lever ratio and a screw and nut for strain compensation.

On the four machines last described, were conducted many of the tests which marked the progress of metallurgy in England and, to a large extent, in the world prior to 1857.[33]

(To be continued)

[32]To Sir Wm. Fairbairn, probably, goes the honor of having first made riveted wrought iron beams which he used in the floors of buildings as early as 1831.

[33]Sir Wm. Fairbairn. Papers on cast iron. *Transactions Manchester Philosophical Society*, 1837 and 1840.

Tests of Riveted Joints. *Transactions Royal Society*, 1850.

Strength of Iron at different temperatures. *British Association, Reports*, 1856.

Resistance of tubes to collapse. *Transactions Royal Society*, 1858.

Experiments on resistance to continued alternations of stress. *Transactions Royal Society*, 1864.

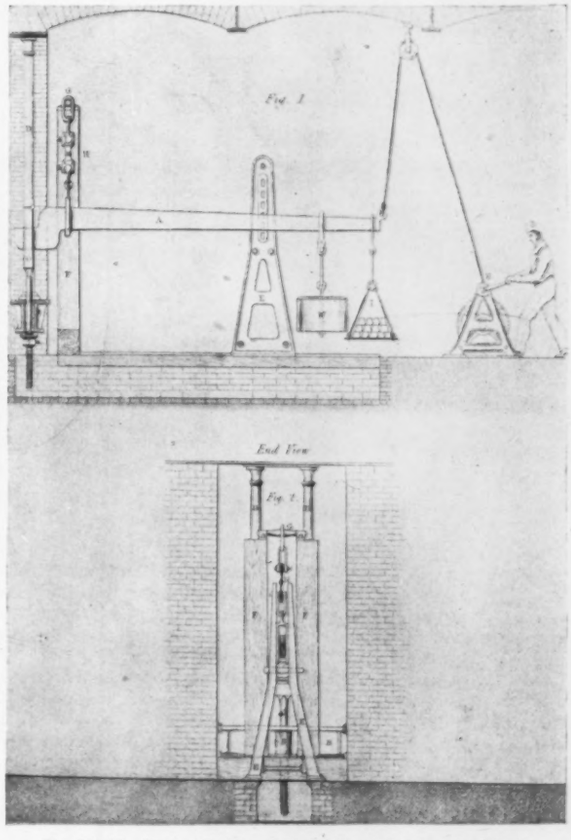


Fig. 15. The Testing Machine of Sir William Fairbairn, about 1848.

LETTERS TO THE EDITOR

The reader and the editor of a technical magazine may be unknown to each other, yet they are closely connected. The reader seeks to learn and benefit by the advances in his field of industry. For that reason he follows his chosen technical magazine. The editor aims to benefit his reader, so you and the editor both strive toward a common interest.

Much is gained by the editor in seeing things with the eyes of the reader. So co-operate in your common interest with him—WRITE TO THE EDITOR. Let him see in your letter the magazine as you see it. If there is something you do not like, or do not believe, or perhaps do not understand, write to the editor. Tell him all about it. In clearing up the matter he may uncover something important which is obvious when close at hand, but at the reader's distance is obscure. This may be of considerable help to other readers as well. To the editor your constructive criticism will be helpful for future guidance, and will be received with friendly appreciation.

Should you miss something in INSTRUMENTS that you feel ought to be there, the editor would like to hear from you about it. Perhaps other readers feel the same lack, then the editor will be pleased to have learned what is required of the magazine, and do his best to fill the requirement. If it is a matter in which you personally want a wider background, the editor feels at all times ready to call on all his facilities or connections and satisfy your inquiry to the fullest.

If you know anything new or more advanced about subjects discussed in the magazine, write to the editor. He will gladly extend your contribution to your fellow readers, giving you due credit.

A Thermal Type Miles-per-gallon Indicator

(*Instruments*, Aug. 1934, page 157)

DISCUSSION

To the Editor:

I was interested in reading in your August issue, on page 157, the description of a thermal type miles-per-gallon indicator. Near the middle of the first column, the statement appears, "the generator which has a steep voltage *vs* speed characteristic curve, supplies heat to the flowing fluid in proportion to the miles per hour." It is not entirely clear to me just what this means.

If the voltage generated is proportionate to the speed and the resistance of the heater is constant, the loss in the heater is proportionate to the square of the voltage and therefore proportional to the square of the speed. Obviously if this relation holds that the heat loss in the heater is proportionate to the square of the speed, the temperature rise as given in the thermopile is not a measure of the miles per gallon.

Perhaps the authors had in mind using a generator in which the voltage characteristic is proportionate to the square root of the speed, or by some other means made the loss in the heater proportional to the first power of the speed. I should be very pleased to be enlightened on this subject.

I have had considerable experience with the use of thermal meters for measuring air volumes and I know that there are quite a number of detail points that must be kept in mind in order to prevent serious errors. It is not entirely clear from the description given as to whether the authors appreciate some of the points that may arise. A number of them are contained in a paper presented before the American Institute of Electrical Engineers in 1928, page 537, entitled "Thermal Volume Meters" by Mr. G. W. Penney and the writer.

Milwaukee, Wis. CARL J. FECHHEIMER,
September 11, 1934 *Consulting Engineer*

AUTHORS' CLOSURE

To the Editor:

The generator which we propose to use with our thermal type of miles-per-gallon indicator is one which will deliver electrical energy to a fixed resistance in direct proportion to its speed of rotation. The voltage generated in this case would vary as the square root of the speed, as Mr. Fechheimer points out, or $E = c\sqrt{S}$ where c is a constant. In our statement that the generator must have a steep voltage *vs.* speed characteristic curve, we had reference to the value of the constant c. What we desire is that the rate of change of the voltage with the speed will be large so that sufficient energy is produced at low speeds to produce a measurable temperature difference.

1703 Cleveland Avenue, J. B. HAMBLEN
Whiting, Ind. W. B. KAY
October 23, 1934.

Instrumentation Terms

To the Editor:

Your editorial in the August issue entitled "Instrumentation Terms" brings up in a forcible manner a matter that has been considered for some time by the standardizing groups of our engineering societies.

The Instruments and Measurements Committee of the A.I.E.E. has a subcommittee on Instrument Standards, one on recording instrument standards, and subcommittees on Telemeters, etc.

There is also a subcommittee working jointly with the subcommittee No. 4 of the A.S.A. for definitions on Instruments and Testing.

The A.I.E.E. Standard No. 33 covers electrical measuring instruments. This is being re-issued in revised form, including much new matter.

Standard No. 40 on recording instruments has been published in the form of a "report."

Report No. 2 of the A.S.A., printed by A.I.E.E., covers "American Standard Definitions of Electrical Terms," including instruments.

The above would seem to comprise authoritative information for all instrument engineering nomenclature.

Some of the standard definitions adopted were chosen for reasons more or less independent of common usage, the idea being to lead to what the committees thought should be the best practice. But common acceptance is proving to be of greater force than "standardization," a condition which is not peculiar to instruments, but which leads to confusion such as described in your editorial.

Three examples of this condition are outstanding as follows:

(1) The word "meter" is by above standard definitions limited to integrating devices such as "watthour meters." General usage, however, employs the word in its broader meaning, exemplified in "ammeters," "voltmeters," and other indicating devices which measure. Usage finds it hard to reconcile the acceptance of terms such as "ammeter," "voltmeter," "power factor meter," etc. with the "legislated" definition of "meter."

(2) The name "recording instrument" as standardized is possibly better than "graphic instrument," but the name "graphic" persists in general usage.

(3) The name "permanent magnet moving coil" instrument is rather long, and the generally accepted name is "d'Arsonval."

In the case of non-technical language, the leading lexicographers seek to determine the existing best usage as exemplified by the best writers and revise their dictionaries accordingly.

But in the case of technical definitions, the situation is different as nomenclature in the exact sciences must be on an exact basis.

In nomenclature the engineers and the editors are in a prime position to direct or guide best usage. This best usage can be no other than the standard definitions which were adopted by the A. S. A.

Let us have no more "meter" instead of "instrument," no more "graphics," and no more "d'Arsonval."

Westinghouse E. & M. Co. PAUL MACGAHAN
Newark, N. J., Nov. 5, 1934

Production and Maintenance of Vacuum

(Concluded from page 250)

rid of adsorbed or absorbed moisture or gases. A satisfactory pumping system for metal vacuum systems of large volume is comprised of a three-stage mercury diffusion pump with a single-stage oil pump as a backing pump. Evacuation of large volume requires short, large-diameter connections and high-capacity pumps.

The variety of pumps and gages available to the vacuum technician allows a selection of the type of equipment which will be best suited to the application. Troubles that occur must be treated in a logical manner so that they may be solved in the shortest possible time. High efficiency systems cannot be constructed by guesswork; they must be designed by methods which have been tested by theory and experience.

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[2]The Production & Measurement of Low Pressure. By F. H. Newman. VanNostrand, 1925.
[3]Air Pumps. Glazebrook's. Dictionary of Applied Physics, Vol. 1, pages 2-24; bibliography, pages 24-25.
[4]Measurements in Electrical Engineering by Means of Cathode Rays. MacGregor. By Morris and Mines. *Journal of the Institute of Electrical Engineers*, Vol. 63, Nov. 1925, pages 1066-1070.

Recording Electrical Instruments

PART ONE—DIRECT-ACTING*

By PERRY A. BORDEN† and M. F. BEHAR**

1. Principal Uses of Recording Electrical Instruments

(a) Definitions and Scope

Recorders to be dealt with here are those for electrical measurements in the strict sense—"recording electrical instruments" as distinguished from "electrical recording instruments" which would take in temperature recorders, recording tachometers, recording flowmeters and other classes, all discussed thoroughly in the other volumes of this Manual. Oscillographs, too, are recording electrical instruments, but so highly specialized as to require a separate treatment in a subsequent article. The scope of the present discussion thus narrows down to the switchboard or portable industrial instruments which can produce a permanent record of the value of an electrical magnitude as a function of time—this graphic record usually taking the form of a curve on a paper chart which has time graduations printed on it. Such instruments render extremely valuable and greatly diversified services in all branches of industry. In general they have two more or less distinct uses, requiring different degrees of accuracy and different operating characteristics. These are (1) statistical and supervisory; and (2) establishment of charges for electrical service. A third kind of service, related to (1) and (2), is in the power plant.

(b) Recorders in Statistical and Supervisory Work

Statistical and supervisory work includes those applications wherein the records are used primarily to furnish a general indication of the shape of the curve representing the duty cycle of an apparatus under test, a piece of production equipment or a department, so that variations may be followed up and their significance investigated. While much work of this nature has been done in isolated cases, it may truly be said that here is a fallow field for the

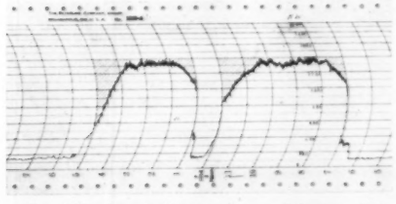

Fig. 40-1. Record of power consumed in one plant. Shaded areas represent "a loss of 11.8 percent of the productive effort of the employees." (Esterline-Angus.)

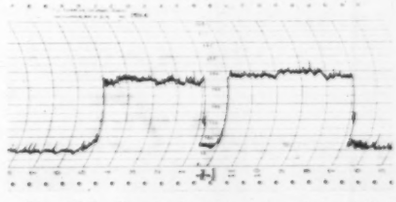

Fig. 40-2. Record of power consumed in another plant. Shop employees begin work promptly and do not anticipate quitting time. (Esterline-Angus.)

application of recording instruments. A *recording ammeter or wattmeter* installed on the circuit to a machine or a department in a manufacturing plant, or on a certain feeder or group of feeders, furnishes an example of such an application. Peculiarities in the process, normal or abnormal adjustment of machines, the condition of cutting tools or dies, the falling off of load as quitting time approaches and the slow pick-up after work is resumed, and the overlapping of load by machines whose duty cycles might be staggered, are among the many subjects which lend themselves to study with recorders so installed. Figs. 40-1 and 40-2 will serve to show how the chart from a curve-drawing instrument is in every sense of the words a graphic record of plant conditions.

While much of the recording of plant conditions has been done by portable instruments temporarily installed on the circuits supplying the loads under study, some *permanent installations* of recorders have been made, enabling a close and continual supervision of operations. For instance, apparatus for the irradiation of milk in dairies includes a recording ammeter as standard equipment and the surveillance of the process is based on the records from this instrument.

*Twelfth chapter (XL) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A of November 1933 *Instruments*. A complete chapter of this new handbook will be published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

†Member A.I.E.E. **Editor, *Instruments*

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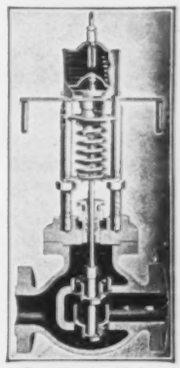

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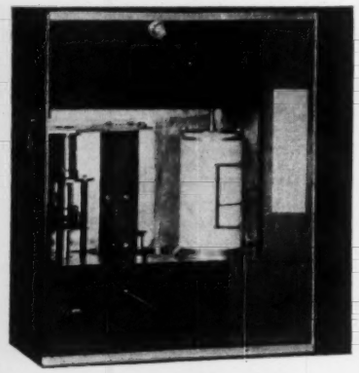

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Such process studies as have thus far been made point to the universal need of a broader application of the practice; and there is no doubt that the near future will see many permanent installations of inexpensive types of recording ammeters or wattmeters furnishing individual records of the performance of machines, machine-tools and processing equipment in manufacturing establishments.

(c) Recorders for Billing Purposes

In the determination of demands and the establishment of charges for electrical service, the application of the graphic instrument is relatively limited; but where so used the results are highly satisfying, and the cost of an instrument of a relatively high degree of precision is justified. In general, it may be said that the maximum demand of a power load, where incorporated in the contract, may be determined with greater facility from some one of the various types of indicating or *recording demand meters,* while a measure of actual energy consumption may be obtained from the registration of a watthour meter with less cost, less trouble, and higher precision than by the somewhat laborious process of determining the area of the record on a graphic wattmeter chart.

(d) Power Plant Recorders

Owing to the widespread interconnection of electric power transmission systems, *frequency recorders* are used today in relatively small numbers; but where they are employed their records are usually of sufficient importance to justify instruments of a high degree of precision. Though the use of clock-controlled or regulated frequency on power systems is becoming almost universal, so that the total number of alternations throughout the day is substantially fixed, it does not follow that the instantaneous frequency is at all times constant; and a frequency recorder furnishes a valuable check-up on the efficiency of the automatic control devices as well as on the alertness and speed displayed by the engineers in charge when the automatic devices become inoperative.

While it is desirable that the power factor of a system be known at all times, particularly during peaks of load, the *recording power factor meter* is somewhat less important as a piece of switchboard equipment than it was two decades ago—probably because in modern conceptions of a-c. power loads that magnitude known as "reactive volt-amperes" is generally of more interest than is the power factor. Power factor can at any time be derived from the concurrent readings of a wattmeter and a reactive volt-ampere meter; and the latter instrument has the great advantage that, while its cost and mechanical structure are practically identical with those of a wattmeter, it may be so installed that by the turn of a switch* it becomes a wattmeter, furnishing a check on the system wattmeter and serving to replace it when it is temporarily cut out for calibration, adjustment or repair.

Recording voltmeter charts give information of great value; and the more complete the installation of such instruments the better the check available on the regulation of the system. The voltage of a system, unlike the frequency, varies from point to point. Voltage records serve as a measure of the adequacy of the system to supply the loads demanded of it, and may thus be made the basis of remedial measures, as well as a means of settling controversies.

2. Classifications of Recorders

(a) By "Grades"

In the foregoing review of principal uses, the various degrees of precision and of accuracy required for different services were mentioned. Herein lies a striking difference between indicators and recorders: there are many grades of indicators, from some laboratory Standards (error one part in a million) to miniature models for automobile instrument boards, etc. (error five percent), and any schoolboy could tell which is which; but recording electrical instruments all come within a narrow grade-class; the lowest-cost portable model having an error (at mid-scale) which probably is not more than twenty times that of a superlatively built self-balancing recorder—the error of each instrument being expressed alike in percent of scale range. This is because there are practical limits to the attainable accuracy of recorders.

(b) By Measuring Functions and by Measuring Principles

Recorders may, of course, be classified according to the various electrical magnitude which they measure and record. Thus we have recording ammeters, voltmeters, wattmeters and frequency meters as the principal classes, with various other special-purpose recorders corresponding to other indicators. The authors have decided, however, not to follow this scheme in making up the divisions of a treatment of recorders *as recorders.* The same applies to a hypo-

*See *Instruments,* July 1934, page 142, Figs. 35-9 and 35-10.

thetical classification of recorders by classes of measuring elements: indicators are divided into four distinct classes, according to the four basic principles, namely, (1) electrothermal, (2) electrochemical, (3) electromagnetic and (4) electrostatic, but nearly all commercially-produced recorders have measuring elements employing some practical application of the *electromagnetic* principle and, as was stated in an earlier article, the measuring elements of electromagnetic ammeters, voltmeters and wattmeters need not differ materially in mechanical details. Finally, in considering electrical recorders as recorders, there is no need of classifying them and discussing them separately according to the kind of current with which the elements operate, namely (1) d.c. only, (2) both d.c. and a.c., and (3) a.c. only; although this was necessary in discussing measuring elements as such. Sufficient be it to list these as has been done above; the reasons for a new basis for dividing detailed discussions will presently appear.

(c) By Measuring Mechanisms

The measuring elements of recording electrical instruments differ from the measuring elements of non-electrical industrial instruments (such as Bourdon tube, cylinder-and-piston, mercury-and-float, fly-ball, expanding-rod, etc.) in that the actuating force is relatively small. This relatively small mechanical force must nevertheless produce a graphic record without undue sacrifice of accuracy.

One solution of the problem is to choose a measuring element of a form which provides the greatest mechanical force in proportion to the energy expended.

TABLE 40-1—CLASSIFICATION OF RECORDING ELECTRICAL INSTRUMENTS

Class	Type	Variety
Direct-acting (also known as direct-deflection)	Intermittent-marking	Dotting
		Thread
		Ribbon
		Smoked-chart
		Spark
	Direct-writing	Ink in pen
		Stationary reservoir
		Photographic
Relay	Electric contact	In this class the varieties do not depend on the type of relay, most being possible with any of the three types
	Mechanical	
	Electronic	

Another solution is to make the measuring element's pointer both long enough to swing over a wide chart-scale and light in weight, and to use an external source of power to press the tip of the pointer at regular intervals on (*a*) an inked ribbon held over the paper chart, leaving a dark mark on the white surface, or on (*b*) a thin layer of carbon, leaving a white mark through the black overlay.

Another solution is to use a large-size measuring element having a relatively short pen-arm, whose mechanical drag will not cause a serious error.

Another solution is to do away with a pen-arm and have the measuring element command the writing mechanism without any drag at all, through a relay and an auxiliary source of power permitting the employment of a motor which does the actual work of inking or printing the curve on as wide a chart as may be desired.

Other solutions could be mentioned but it has now become apparent that the most logical way to deal with recording electrical instruments is by considering the whole of the measuring mechanism—the combination of the electrical measuring element and of the writing mechanism. Recording electrical instruments

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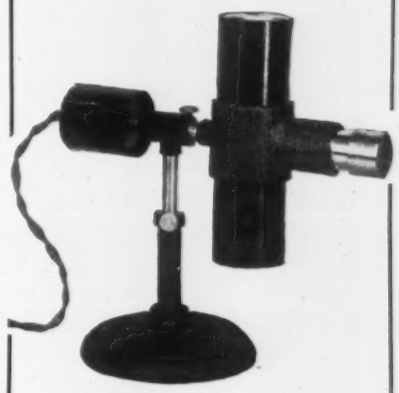

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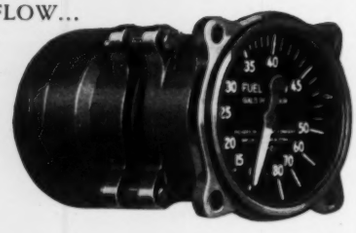

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are logically classified with regard to the manner in which the marking device is related to the measuring element. Table 40-1 shows the scheme herein adopted. Direct-acting recorders will be discussed in this article; relay recorders in next month's article; but before dealing with them separately, it may not be amiss to consider the general characteristics and features common to direct-acting and relay recorders alike.

3. Characteristics and Features Common to Both Classes

(a) Accuracy

An ideally accurate recording instrument would produce a curve of all successive instantaneous values of the magnitude to which it is applied. In practice the term "instantaneous values" is only relative; for few, if any recording instruments other than cathode-ray oscillographs can be said to follow and record every variation in the measured magnitude. Even if it were practicable to design and build such an instrument, the records obtained on a reasonably wide chart traveling at reasonable speed would be so blurred as to limit their usefulness, while records on a chart as wide as a bed-sheet traveling at a foot per second would only be called for by richly-endowed research laboratories. Damping is essential to the satisfactory performance of an industrial recorder. Damping devices as such will be discussed later on; the subject is only brought up here to point out that "accuracy" undergoes a change of meaning when a fluctuating magnitude is to be recorded.

But even in the recording of slowly changing values there are practical limits to the attainable accuracy of an industrial recorder. First comes the necessity for a record which can be read easily, whether it be a line or a series of dots, and therefore must have an appreciable *width*.

Next may be mentioned the effect on paper of *humidity*, the error from this source being proportional to (1) the hygroscopic coefficient of the paper, (2) the distance of the record from the fixed point—the center of a round chart or the guiding edge of a strip chart, and (3) the difference between the humidity of the air in which the chart was printed and that of the air at the location where the record was made. This hygroscopic error *may* amount to as much as 3% of the scale range under exceptionally poor conditions, but when instructions are followed it should not exceed 0.25%. Users should do their utmost to minimize it, particularly when the instrument is a high-grade recorder with an *intrinsic* accuracy of 0.1%.

Another limit to the attainable accuracy of a recorder is imposed by the *price* which users are willing to pay for charts: not only would most purchasing agents veto the idea of buying charts made of a non-hygroscopic material instead of paper, but many of them turn a deaf ear to engineers' pleas and shop around for the cheapest paper charts, which usually are not printed and perforated in one operation, and which otherwise cause a recorder of excellent *intrinsic* accuracy to produce erratic records.

One way of minimizing both the hygroscopic error and the off-register error is to use the charts supplied by the maker of the recorder and to follow his instructions.

Another limit not only to accuracy but also to precision, is the problem of utilizing a weak actuating force. None of the solutions mentioned in Section 2 is ideal. At one extreme we have utmost simplicity, with sources of error reduced in number and minimized in effect (their abolition is impossible); at the other we have total elimination of drag on the moving coil, with a relatively great number of interacting kinematic elements—clutches, gears, pulleys, ratchets, etc.—multiplying sources of error.

European countries have attempted to specify accuracy for recording electrical instruments in definite terms; but the wide limits (found necessary to allow in order not to exclude meritorious types when operating under unfavorable conditions) tend to make it appear that the direct-acting recorder is of little use other than to furnish a "picture" of what is taking place in the circuit. American practice has shown that well designed and honestly built direct-acting strip-chart recorders, when correctly used and free from excessive vibration, stray fields and temperature fluctuations, should without difficulty provide a sustained accuracy well within 2 percent of full scale range. Direct-acting round-chart recorders, despite their inherently shorter scales, may often be operated to an equally high degree of accuracy.

(b) Chart Forms

An industrial electrical recorder produces records on either a round chart with substantially polar coördinates or on a strip chart with substantially rectangular coördinates. An individual instrument cannot be converted from one to the other in practice; but whichever form of chart is desired, either a direct-acting recorder or a relay recorder may be found which uses it. At this writing, however, the majority of relay recorders are strip-chart instruments and the majority of round-chart instruments are direct-acting recorders.

On a round chart, the scale length is necessarily less than the radius. Moreover, since the spaces at the center and at the edges cannot be over-minimized, the scale length of a small-size round chart is not much more than half the radius while in a large-size round chart it may be three-quarters thereof.

On a strip chart, nearly the whole width of the paper is available for the scale of measured values. Therefore, a strip chart—and a wide one at that—is preferred where the measured magnitude is normally so *steady* that the full sensitivity and accuracy of a high-grade measuring mechanism may be used. In many industrial applications, where considerable damping is essential to prevent blurred records, small round-chart recorders often prove just as satisfactory.

For statistical work, as in taking time-operation records of machine tools, a wide record is a useless luxury and "miniature" records can serve the purpose. For measurements upon whose precision monetary transactions are directly based it always pays to specify the most "open-scale" strip-chart recorder.

(c) Chart Period

Various types of spring and of electric chart drives are available, each particular type having some distinctive feature, but there is no need of discussing their details here, and the only point worth emphasizing is that where interruptions of a.-c. supply are frequent, spring-driven charts provide records showing both the clock time and the duration of each interruption.

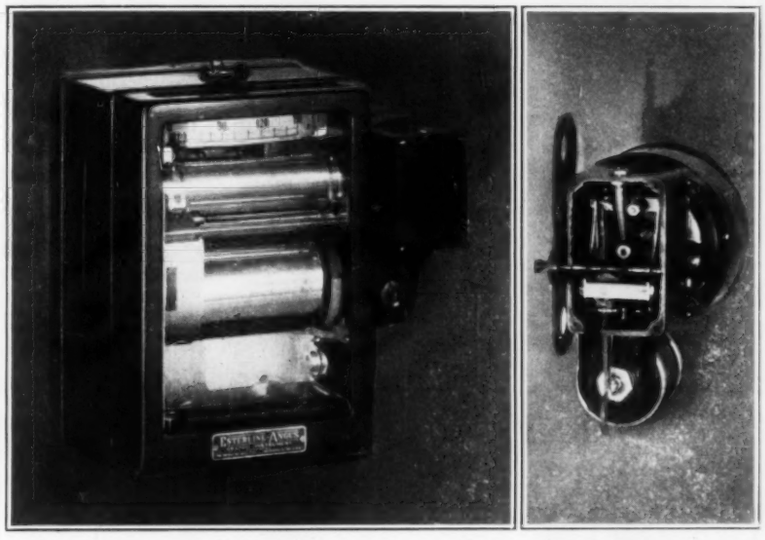

Fig. 40-3. For recording normal operation on a slow chart speed and also making a record on the same chart moving at high speed during the time a disturbance is taking place, the "Quick Trip Device" is an attachment which, through a relay, instantly speeds up the chart to 3600 times normal and which resets the chart to correct time when the disturbance ends. (Esterline-Angus.)

The chart drive of a round-chart recorder, whether spring or electric, generally has only one speed (8-hour, 24-hour, 7-day, etc.) so that the drive must be replaced in the event that the user desires, for example, to change from 8-hour to 12-hour charts. A few round-chart recorders and many strip-chart recorders are supplied with change gears, so that chart speed may conveniently be set to the user's requirements after the instrument has left the factory.

Speed-changing devices are available also in which the gear shift is accomplished merely by shifting a lever; and at least one manufacturer (Esterline-Angus) regularly supplies recorders in which the chart is *automatically* speeded up 3600 times in case of trouble in the system, so that a detailed record of occurrences may be obtained on an expanded time scale. See Fig. 40-3.

The strip chart being supplied as a roll, may be many feet in length, corresponding to days or weeks—this duration, of course, being governed by the speed, which is selected in accordance with the precision of time measurement required for the work in hand.

(d) Suppressed Zero Feature

There are many electrical engineering applications where the requirement is constancy. This may be achieved by manual adjustments or by the use of automatic regulators, or by alertness in control of loads; but since the greatest interest always lies in a limited range on both sides of the ideal value, the most useful recorders for such installations are those with narrow-range charts, such as "55 to 65" instead of "0 to 65" for the whole chart scale. This feature of

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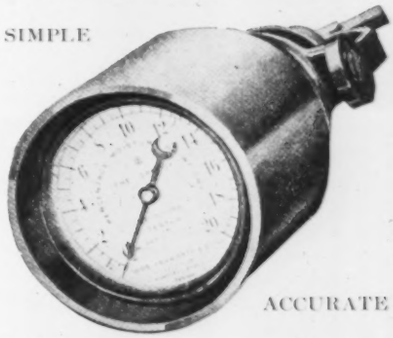

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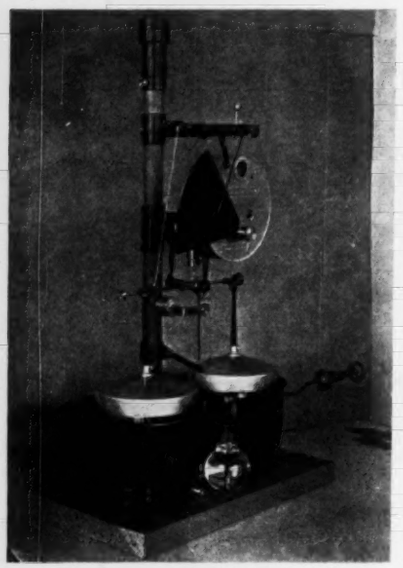

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CORRIGENDA

Reflection Method Geophysical Equipment — American Askania Corp. and Heiland Research Corp. (September issue, page 196.) Fourth line from end of item, sensitivity is given as of the order of 0.1 to 0.2 ma./mm. Should be 0.01 to 0.02 ma./mm.

Welding Timer — Westinghouse Elec. & Mfg. Co. (November issue, page 240.) Wherever the word "ignition" appears in this manufacturer's story, it should be "Ignitron."

zero suppression may be obtained by employing measuring elements of types that operate without control springs and have been purposely designed to have inherent ranges corresponding to those of the recorder charts; or it may be obtained by having the full recorder range represent the unbalance of a circuit; but in most industrial applications—particularly in the recording of voltage—the measuring element is of a type which depends on opposing the actuating force by that of a spring. When a recording voltmeter, for example, is desired to have a suppressed zero, this is done as follows: To the normal action of the control is added a constant force, restraining the pen until the measured voltage reaches the lower limit of the scale, after which a relatively small increase in the measured voltage carries the pen to the upper limit of the scale. For applications where the normal voltage is 110 or 115, a common range for such instruments is from 90 to 140 volts. Where zero suppression is obtained by simply setting back the zero, as by rotating the abutment of the control spring through an initial angle, it is necessary to make use of a spring considerably weaker than would otherwise be considered good practice, and to submit it to a large initial strain. For this reason such a recorder with suppressed zero, though it be of high *sensitivity*, is not likely—unless designed and constructed with extraordinary care—to have the *accuracy* of one with a full scale starting at zero.

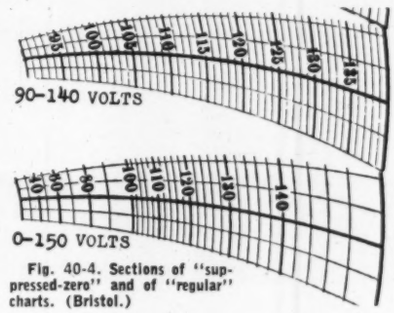

Fig. 40-4. Sections of "suppressed-zero" and of "regular" charts. (Bristol.)

4. Direct-acting Recorders

Direct-acting recording instruments are those in which the marking device is mechanically connected to, and directly operated by, the moving element. They are divided into (*a*) intermittent-marking and (*b*) direct-writing.

(a) Intermittent-marking

The feature of intermittent-marking is confined mostly to galvanometers as distinguished from ammeters, voltmeters, etc. In other words it is found in recorders for directly measuring relatively minute amounts of electrical power, as in the circuits of pyrometers,* resistance thermometers,* sunshine recorders, etc., where a small electric current—perhaps a few milliamperes—is made to be directly representative of a magnitude of another nature, whose value it is required to record. Intermittent-marking recorders may be conveniently divided into: (1) dotting, (2) thread, (3) ribbon, (4) smoked-chart, (5) spark. A characteristic of intermittent-marking recorders worth noting here is that multiple-record models are available, in which an automatic commutating device connects a plurality of circuits in sequence and the several records are all made on one chart.

In the *dotting* type of recorder a light pen carried on the end of the pen-arm normally swings free of the chart. A mechanism, which may be either in the form of an electromagnet or a depressor-bar operated from the clock which drives the chart, brings the pen momentarily into contact with the paper at brief intervals, leaving it the rest of the time free to be positioned by the measuring element. The series of dots so formed merges into a line and, where the

*Several recorders of this type, used in conjunction with pyrometer circuits, have been described in Part Two of this Manual (Temperature Measurement and Control).

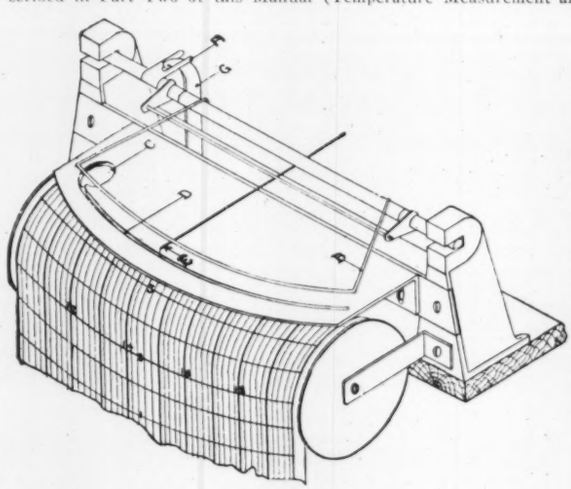

Fig. 40-5. "Capillary Film" recorder. When free, the galvanometer needle, which carries a fine wire E, bent downward, swings above a V-shaped slot, D, in a metal sheet mounted horizontally above the drum. This slot tapering slightly in its length, the ink flows freely from well C, to the extreme end. Lever G is periodically lifted by the wheel on the clock face, and depresses B upon the needle, forcing it down through slot D, carrying on the point of wire E a dot of ink which is deposited on the chart. "No more ink than is needed can be deposited upon the chart in the time it is depressed, and ink will not follow the wire and flow down upon the chart, as might be supposed." (Thwing Instrument Co.)

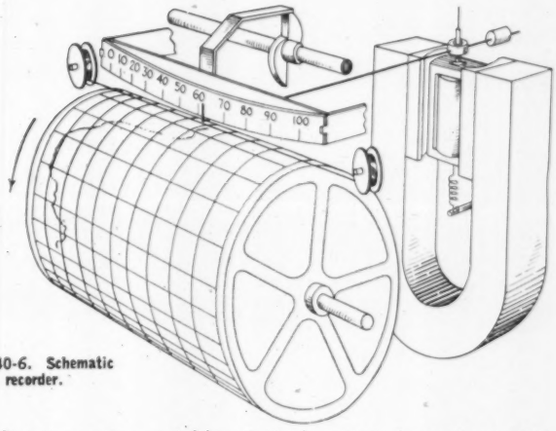

Fig. 40-6. Schematic of thread recorder.

measured value is not too variable, gives the equivalent of a continuous record. In the Thwing dotting recorder, Fig. 40-5, the pen-arm does not carry a pen but makes use of an ingenious capillary principle explained in the caption.

In the *thread recorder,* Fig. 40-6, the pointer of a direct-deflecting galvanometer swings above the paper chart, which passes over a firm platen. Between the pointer and the paper is stretched an inked thread which is slowly fed across the path of travel of the chart. At regular intervals a depressor bar brings the pointer into contact with the thread, and forces the latter against the surface of the paper, leaving an impression in the form of a short dash.

In the *ribbon recorder,* a typewriter ribbon takes the place of the thread, and the pointer, ribbon and chart are forced into engagement against a sharp-edged platen, giving a distinct dot on the paper. This ribbon may be above the chart or under the chart (using a thin translucent paper). Some makers, notably Bristol, supply both styles.

Both the thread and ribbon methods of intermittent marking make possible *color identification* of the separate records which are obtained on one chart by using a multiple-switch to connect a plurality of circuits in regular rotation: the same mechanism that operates the multiple-switch shifts from one thread to another (as in the Cambridge recorders) or shifts a multicolor ribbon from one stripe to another (as in the Brown Instrument Co.'s recorders).

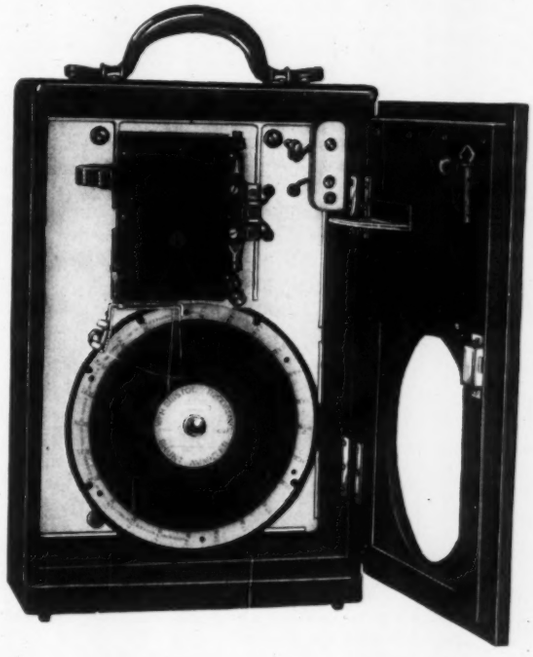

Fig. 40-7. Bristol portable smoked-chart millivoltmeter.

In the *smoked-chart recorder,* the paper surface is covered by a thin layer of finely divided carbon. The pointer normally swings just clear of this surface, and an arm operated by the clock causes the tip of the pointer to touch the chart every few seconds. This breaks the thin black layer on the surface, making the paper visible and giving the effect of a white line on a black background. Such charts require careful handling until removed from the instrument, when the record is made permanent by immersion in a suitable fixative. A Bristol smoked-chart recorder is shown in Fig. 40-7.

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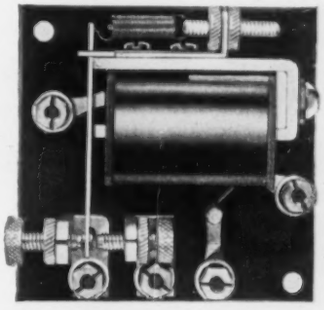

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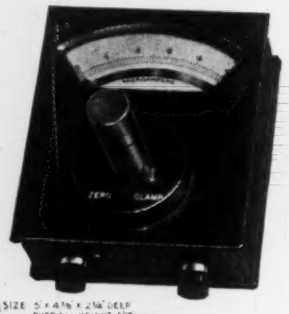

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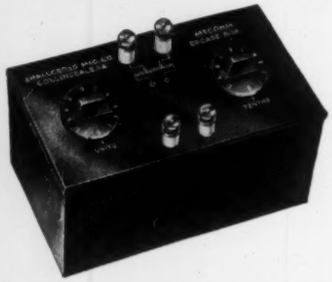

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Some early types provided a record in the form of a series of punctures by an electric *spark* jumping between the pointer and the platen, but this method has not found favor in American industrial practice.

(b) Direct-writing

For recording voltage, current, power, etc., in power houses and industrial plants, few intermittent recorders are in service: this field belongs to the direct-writing type and to the relay class.

With regard to marking mechanisms, direct-writing recorders may be divided as shown in Table 40-1, but photographic recorders are not of sufficient industrial interest to be dealt with here, so that as far as we are concerned the direct-writing type consists entirely of direct-*inking* recorders. The division of these into: (*a*) ink in pen and (*b*) stationary reservoir, agrees with the basic scheme of classification by writing mechanisms, but experience with all makes and forms of direct-writing (direct-inking) recorders in a wide variety of services leads to the conclusion that direct-writing recorders naturally divide themselves into the round-chart and the strip-chart recorders—two distinct groups with important inherent differences of characteristics.

In direct-writing *round-chart* recorders the pen-arm is generally arranged to swing in a vertical plane; and since, whatever the chart speed, the pen need only hold a few drops of ink to trace a record for one complete revolution, it may be light and simple. In round-chart ammeters and voltmeters, the moving-iron principle is widely used, though the electrodynamic principle in the form

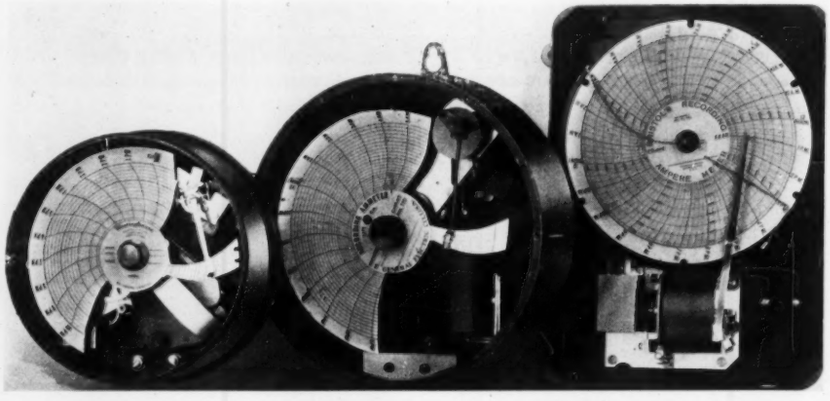

Fig. 40-8. Westinghouse, General Electric and Bristol round-chart direct-writing ammeters. (Charts and chart plates cut away where necessary to show movements.) These are all switchboard recorders.

of the attracted or repelled flat coil is employed to some extent. Fig. 40-8 shows three well-known makes of round-chart recorders. The Westinghouse instrument uses a rotating moving-iron type of movement with magnetic damping. The General Electric instrument employs a plunger in a vertical solenoid. It also is magnetically damped. The Bristol recorder employs a plunger supported on knife-edges and moving in a horizontal solenoid. Damping is effected by means of an oil dashpot. These instruments are available with either electric or spring-driven clocks.

Direct-writing *strip-chart* instruments are generally built with a vertical shaft, the pen traveling in an arc over the chart in a horizontal plane near the top of the case. Practically the whole width of the paper is thus available for record purposes.

The pen of a direct-writing recorder describes a curved path in the plane of the paper, but this feature is seldom objectionable, and the added complication

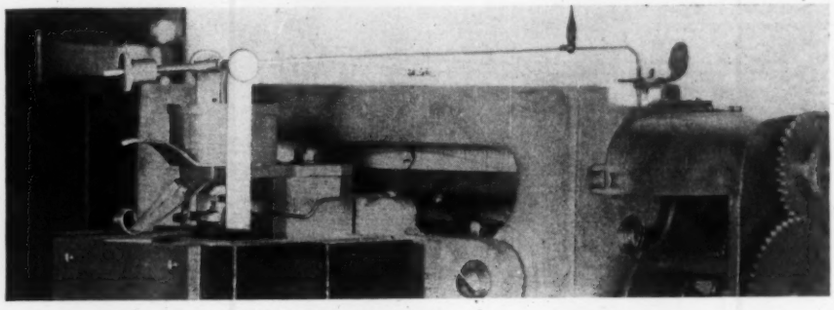

Fig. 40-9. Close-up of Roller-Smith permanent-magnet moving-coil strip-chart direct-writing recorder.

needed to obtain truly rectangular coördinates in a direct-writing strip-chart instrument is seldom justified.

The problem of inking is greater with strip-chart than with round-chart direct-writing instruments. Since the strip record is continuous, and may be required to run several weeks without attention, a rather large amount of ink must be made available to a necessarily light pen. A widely used form of pen-arm is a capillary tube receiving its ink supply from a reservoir near the center and syphoning it onto the chart. In Roller-Smith recorders the reservoir is at the exact center. See Fig. 40-9.

The electrodynamic principle lends itself particularly well to the strip-chart form of design, and is widely used in voltmeters, ammeters, wattmeters, frequency meters and power factor meters. For direct-current measurements the permanent-magnet moving-coil type of element is well adapted to the strip instrument. Characteristic American types of direct-writing strip-chart electrical recorders are shown in Figs. 40-10 to 40-12.

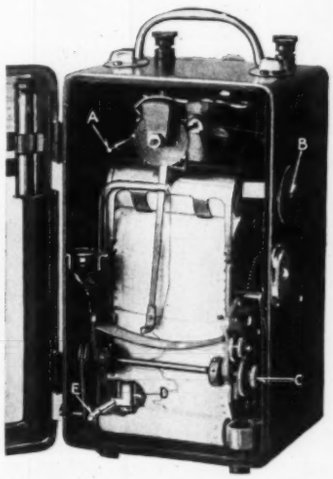

Fig. 40-10. Westinghouse portable strip-chart direct-writing recorder.

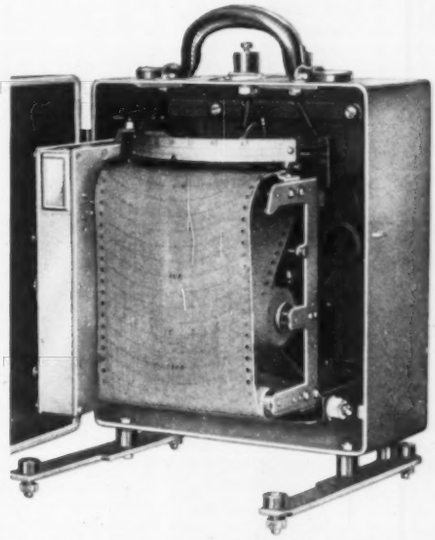

Fig. 40-11. Bristol portable strip-chart direct-writing recorder.

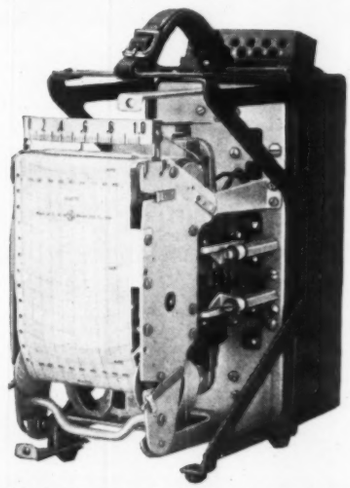

Fig. 40-12. General Electric portable strip-chart direct-writing recorder.

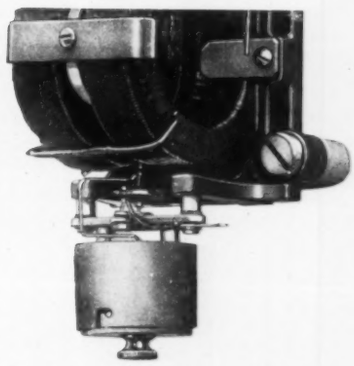

Fig. 40-13. Oil damper for strip-chart recorder (Bristol).

Damping. The relatively large inertia inseparable from the design of direct-writing recorders, and the fact that every movement of the pen leaves a permanent trace on the chart, make it necessary to damp out oscillations effectively. Both liquid and magnetic damping are used. On instruments having a vertical shaft, the damping members take the form either of a vane (of aluminum or copper) swinging in the field of permanent magnets, or of a dasher rotating in a vessel containing oil or some other viscous liquid (Fig. 40-13). While magnetic damping is more convenient where only moderate fluctuations of the moving element are encountered, instruments for measuring "jumpy" loads often require fluid damping with an oil of relatively high viscosity.

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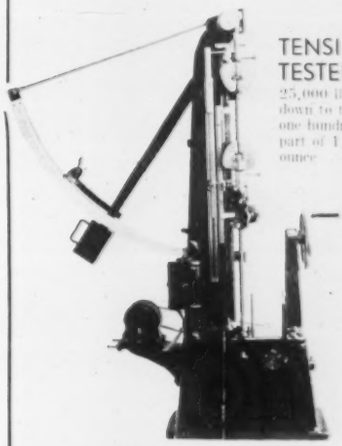

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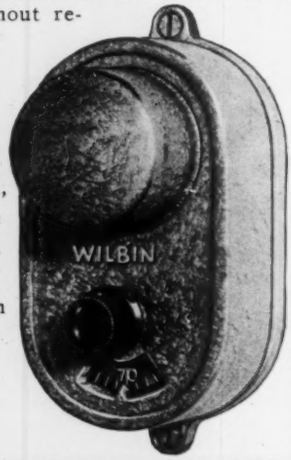

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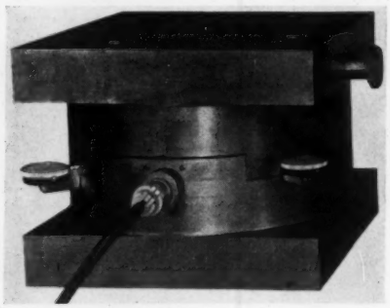

ing is encircled by two bands carrying screws adjusted to touch cylindrical surface. Ends of bands approach each other but do not touch. Connected to ends is an Inductor Telemeter. Loads on the cylinder increase its circumference, thereby causing ends of encircling bands to separate. This displacement is translated into electrical current which can be read at a distance or may be conducted through an oscillograph to produce a permanent record. Previous calibration permits a translation of such electrical indication into pounds load.

Industrial Boiler Meter

Bailey Meter Co.

TO supply increasing demand of industrial establishments for higher boiler room economy, this new Steam Flow-Air Flow Boiler Meter records steam flow from the boiler, air flow supplied for combustion and flue gas temperature—all on one 12″ diam. uniformly graduated chart. It also indicates steam flow on a porcelain enameled scale and integrates the total steam flow on a 6-digit cyclometer counter. Thus the three important factors of boiler operation—combustion efficiency, steam output, and flue gas temperature—are combined and coördinated. Meter is equipped with direct-reading Bailey escapement type integrator fully described in *Instruments*, March 1933, page 65. Air flow mechanism provides for quick and accurate adjustment to prevailing combustion conditions. Though sturdy in construction and powerful in operation, it is said to possess inherent accuracy and sensitivity. Simplicity, accuracy and flexibility are said to be combined in the new steam flow mechanism by using a powerful Bailey Ledoux Bell in conjunction with interchangeable mercury reservoirs. In operation, new meter is said to be a reliable combustion guide which any boiler operator can easily understand: It is simply necessary for him to adjust boiler damper or fuel control until records of steam flow and air flow coincide on chart. Because of trend to automaticity in industrial boiler plants, new meter has been designed to fit into the Bailey Meter Control System. In this service, it regulates air supply or stoker speed to achieve combustion efficiency, and maintains steam pressure and furnace draft at the desired standard.

Temperature-limit Control for Furnace Roofs

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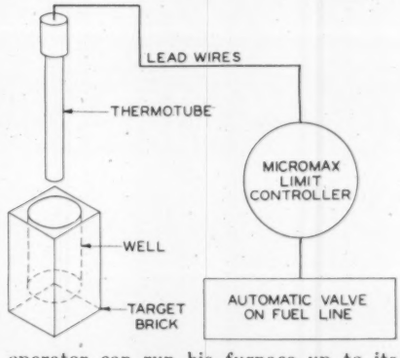
AUTOMATIC fuel cut-down or cut-off, based on measurement of temperature of carborundum block without physical contact, is principle employed in this new system. Overheating of furnace roof being prevented,



operator can run his furnace up to its highest safe temperature without fear that roof will be damaged should his attention be diverted. Number of heats per roof is said to be noticeably increased. *Parts*: (1) Carborundum block of special design, with well drilled to 1″ of bottom. May be installed when roof is being built or while furnace is hot. Lasts for an entire campaign: should bottom burn away, a special plug is dropped in well. (2) Thermotube employing familiar mirror-and-thermocouple principle but of new design with water jacket which serves as mounting. (3) Instrument is 1400-3200° F., 24-hour round-chart "Micromax" potentiometric recorder-controller with wide indicating pointer and 12″ large-figured "giant" outer scale—see *Instruments*, March, 1933, page 63. (4) Motorized valve: as required but always of simple, strong type, as it operates only in emergencies.

Vacuum Gage

Westinghouse Elec. & Mfg. Co.

PIRANI type vacuum tube recently announced has been developed for use in a calibrated instrument which gives continuous pressure readings on exhaust systems on the machines that assemble Mazda lamps. Chief advantage is continuous accurate reading, without the manipulation of any parts as with a McLeod gage.

Heavy-duty Circuit Breakers

Roller-Smith Co.

HIGH interrupting capacity is one of claims for new "Type HD" (heavy duty) circuit breakers, this characteristic being as shown in following test-based table:

Ratings	*Interrupting Capacity*
0-400 amps.	40,000 amps.
401-1200 amps.	60,000 amps.
1201-2000 amps.	80,000 amps.
2001-5000 amps.	100,000 amps.
5001 amps. and over	120,000 amps.

Fig. 1 shows a 4000-amp., 3-pole electrically operated breaker of this new

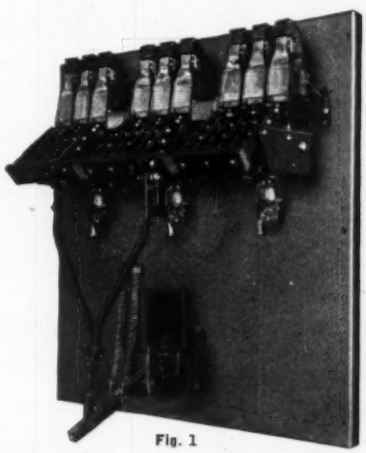


Fig. 1

line. Another characteristic is said to be high overload capacity, due to "inverted" contacts and the "loop" effect of the magnetic circuit, which result in high contact pressure under heavy overload or short circuit conditions. (See Fig. 2 which shows inverted contacts—brush, secondary and carbon.) A third charac-

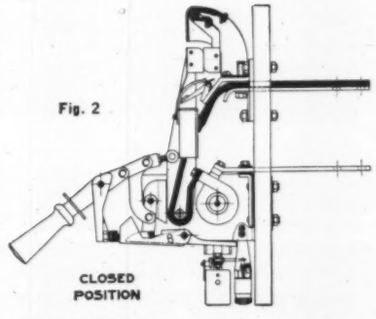


Fig. 2

teristic is high speed of opening, due to the heavy laminated brush being stationary and the moving arm not carrying that heavy member. Calibration scale is long, to facilitate exact settings. All poles on multipole breakers open and close in unison. All breakers are so designed that undervoltage, shunt-trip and other attachments may easily be added in the field.

Recording Gas Gravitometer

George Sidney Binckley

PRODUCED in recognition of importance of specific gravity determination in accurate measurement of gases and in maintenance of heat-balance, new Anubis Recording Gas Gravitometer is said to differ widely in fundamental principle from others tentatively applied under service conditions. Among characteristics are said to be extreme simplicity, absence of any dynamic element in principle of operation, automatic compensation for temperature variations, and direct recording of difference between weights of equal volumes of air and gas. Essential elements comprise:

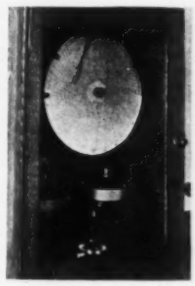


Fig. 1

Two inverted bells, the lower edges of which are submerged at all times in a sealing liquid held in the intercommunicating tanks below them, one of these bells being the "working-bell" and the other the "balance-bell."

A beam from which, through hardened steel knife-edge links, the bells are suspended, and which in turn is supported by hardened steel knife-edge fulcra.

A pendulum arm attached to the beam, and so adjusted that in the absence of the cylindrical pendulum weight itself, the entire system of beam, links, pendulum, thermostatic element, and bells, is in static balance.

The gas-column, a brass tube 1¼" diameter, supporting the chart-driving clock and other mechanism, the height of this column varying with the character of the gas.

A thermostatic element of helical form, attached to the pendulum arm, and provided with a horizontal arm on which is carried the cylindrical pendulum weight.

Flow of gas is regulated by the ⅛" angle valve. Continuous sample (approx. 1 ft³/hr) flows through pressure-limiting water seal in the flask (seen in Fig. 1), through a small stainless-steel orifice and to interior of closed bell which communicates with bottom of gas column. Small orifice has no measurement function, its purpose being to limit rate of flow under low pressure permitted by water-seal, so that this flow can have no kinetic effect upon action of instrument, thus obviating need for accurate pressure or volume regulation. Fig. 2 shows mechanism whereby vertical movement of working-bell is transmitted to the pen-arm. Here, as in suspension of bells and beam, friction is minimized by employment of hardened pivots and by provision of counterbalances. Operation:

The small continuous sample passes from the little orifice to the interior of the working bell, filling it above the surface of the kerosene and passing out into the base of the gas column, thence up this column and out of its upper end to the atmosphere. With the bell and the column thus filled with gas the pressure inside the conical head of the working-bell is more or less than the pressure of the atmosphere on the upper surface of this head, as the gravity of the gas is greater or less than that of the air. Thus, at gravity 1.0, the pen is at its outer range on the chart, the pendulum weight is vertically below the fulcrum, and all forces are in equilibrium. If the unit weight of the gas varies from that of the air, equilibrium is destroyed, and the force acting on the bell causes it to move until the moment of the pendulum weight around the fulcrum equals that due to the force acting on the bell, whereupon equilibrium is re-established, the pen taking a position corresponding to the specific gravity of the gas.

Under standard conditions, 60°F. and 30" Hg, the relations described will be strictly true. Variations from standard temperature produce a change in the air-gas differential which requires compensation. This is accomplished by placing the cylindrical pendulum weight on a horizontal arm carried on the free end of a strong helical coil of thermostatic metal.

The functions of the "balance-bell" are purely compensatory: Placed on the beam at the same distance from the fulcrum as the working-bell, and being of the same weight, temperature effects on the length of the beam are fully compensated. Its walls being the same thickness (0.007") as those of the working-bell, changes in the density of the sealing liquid due to evaporation of its lighter elements or to temperature variations, are compensated. A

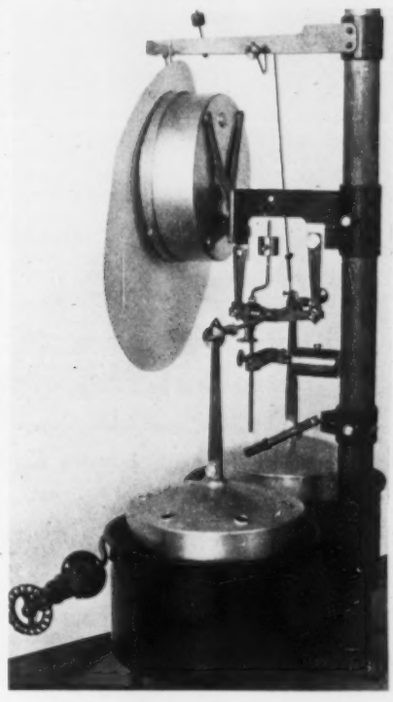


Fig. 2

simple weight, having the same cross-section as that of the walls of the bell submerged in the liquid, could not perform the same compensatory functions because of the surface-tension effect. This is surprisingly great (4.5 g. effective pull) and as it varies both with temperature and with character of liquid, it is imperative that it be balanced by equal superficial areas.

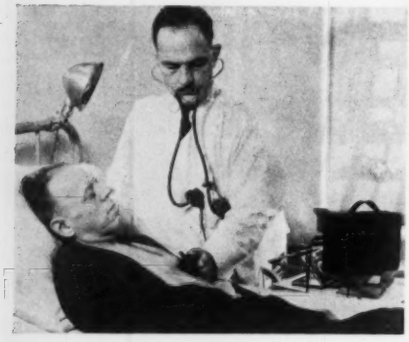
The standard Anubis Gravitometer is adapted to different conditions of altitude by a simple change in height of gas column. The effects of diurnal variations in pressure are so nearly equal and opposite that the barometric coefficient is negligible. When required, however, the instrument is provided with full automatic compensation for barometric changes.

Calibration is easily checked at any time by application of a standard weight, and reference to a table of factors, both furnished with instrument, a record being made on a standard 10" Anubis chart divided to the second place of decimals and readable to the third. (Ultimate sensitivity of instrument is 0.00012" water head.) Having no electrical connections, motors, or regulating valves, it operates under extremes of temperature, and is said to require no attention after installation, other than to wind the clock, change the chart, and ink the pen.

Electrical Stethoscope

Western Electric Co.

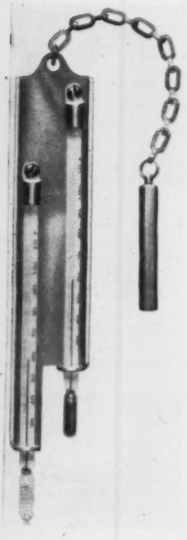
DESIGNED to transmit most efficiently at low audio frequencies ("rumbles," "thumps," etc.) this new self-contained microphone has quickly won noteworthy acceptance in medical field but has applications in vibration



studies and acoustic tests. Pick-up is magnetic. Amplifier (100×) weighs 4 oz., contains 2 "peanut" tubes and 2 miniature transformers with Permalloy cores, employs 4 flashlight cells for filaments and 2 smallest-size dry batteries for plates. Selective switch and filter permit listening to frequencies in <100 and in 200-2000 regions.

Pocket Size Sling Psychrometer

Precision Thermometer & Instru. Co.



TOTAL length is under 6". Two laboratory etched-stem thermometers are mounted on a flanged aluminum plate. Metal handle is on swivel-and-chain to facilitate whirling. User can replace damaged thermometers by means of a small screw driver without returning instrument to factory. Thermometers are graduated from 30° to 110° F., in 1° divisions, calibrated for total immersion, accurate within 1°. Carrying case is reinforced with liner.

PRECISION HYGROMETERS

FOR

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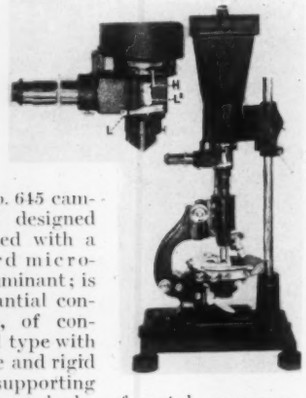
245 W. 55th ST. NEW YORK

Photomicrographic Cameras

Spencer Lens Co.

CONSIDERABLE bellows extension characterizes the No. 640, a 5" x 7" camera, which is equally efficient in either vertical or horizontal position. It is mounted on a base 16" x 12¼", with a rigid upright 30" high on which short heavy arm revolves. At end of arm is hinged a long telescoping bar which supports bellows and plate holder frame, to give an extreme bellows length of 24" or a short bellows of 8". Support at front end of bellows is movable by rack and pinion for convenience in connecting and disconnecting microscope and for careful focusing when micro-teleplat photographic lenses are used. An extension bar, which slides beneath base of camera and an arm hinged to and extending from the base, make a rigid support for camera in horizontal position.



The No. 645 camera was designed to be used with a standard microscope illuminant; is of substantial construction, of conventional type with solid base and rigid vertical supporting rod. Camera body, of metal, accommodates either 3¼" x 4¼" or 4" x 5" double plate holder as specified, and carries a slide focusing specimen on plate from side without changing position of set-up. It is of fixed length, 250 mm. (projection distance to give specimen same magnification on plate as is obtained visually).

Contactors

Ward Leonard Electric Co.

NOW available as separate units, these d.c. and a.c. contactors for several years have been used in maker's control assemblies. They can be used as control contactors for motors, for disconnect purposes in conjunction with suitable auxiliary switches, for electric ovens and other electric control applications, and for special control panels. High contact pressure with low operating and holding currents in the coil are among features claimed. Auxiliary silver-to-silver contacts are furnished as standard equipment for maintaining coil circuit when momentary push button control is used. Additional normally open or normally closed auxiliary contacts can be furnished when required.

Hippel Type Lamp

Fish-Schurman Corp.

JENA GLASS WORKS of Schott & Gen. offer new high-pressure mercury arc: of capillary type, self-striking, completely light shielded, adjusted in height and direction, self-contained, operable in every plane with equally satisfactory results. Steadiness is due to burner (Hippel type) which is self-regulating in the length and position-of-termination of its arc path. Operates on 110 or 220 d-c. When not in operation, burner offers a continuous column of mercury as path of conduction between its end electrodes. But heater-coil being always in series, when voltage is turned on a current of approx. 0.5 amp. is passed. In about one minute enough heat has been generated by heater-coil to vaporize portion of liquid mercury column. When this vapor forces mercury column to break apart, an arc is struck, which by self-generated heat

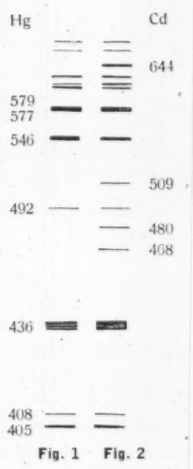
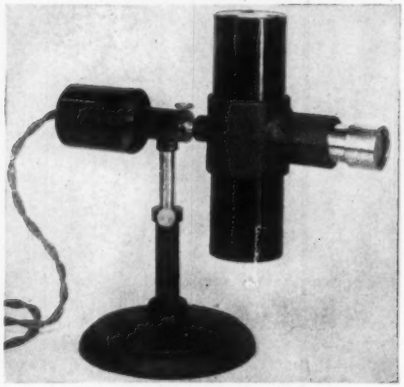


Fig. 1 Fig. 2



maintains itself at such a length that vapor pressure and thermal conditions balance. Current comes to a steady value of approx. 125 ma. in a few minutes (for precision work, about 20 min.). *Filters* regularly furnished isolate principal Hg lines; others available have selective transmissions and absorptions in all regions. Fig. 1 shows Hg spectrum of lamp; Fig. 2 gives the revised spectrum after cadmium is added.

Surface Temperatures

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No. 10

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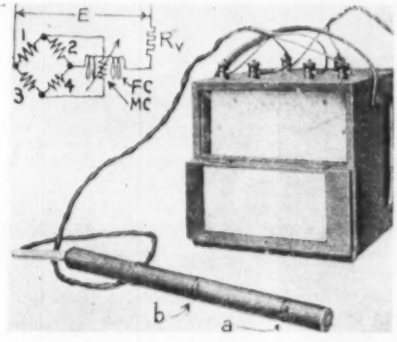
Short Circuit Indicator

Trüb, Täuber & Co.

FOR rapidly detecting presence of short circuited turns in coils wound with copper wire or strip, this outfit employs a.c. bridge principle: Exploring unit comprises four coils, mounted in pairs (1 & 4, 3 & 2) on two iron cores in tandem, all contained in hollow insulated rod. Bridge connections are shown in diagram. Instrument moving coil is connected across bridge, while field winding is in supply circuit through a non-inductive resistor. *Operation:* coil to be tested is slipped over detecting rod and moved back and forth between positions

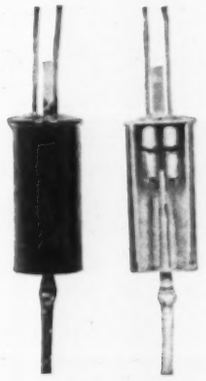


a and *b* (which are marked on rod). Instrument pointer stays at center zero if no turn is short circuited. In factory inspection of coils, deflection is proportional to number of short circuited turns.

All-metal Vacuum Switch

General Electric Co.

SMALL vacuum switch, made almost entirely of steel, designed to take advantage of absence of an arc when breaking a circuit in a high vacuum, is only about ¾" diam. ×1½" long; can be operated by a fraction of

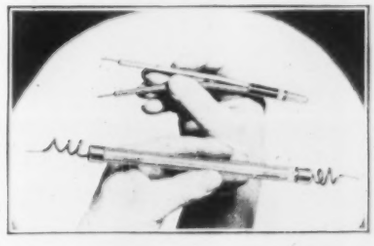


an ounce of pressure; is capable of interrupting as much as 5 h.p. as fast as 30 times a second; is rated at 10 amps., 250 volts d.-c. or 440 volts a.-c.—or 5 amps. at 500 volts d.-c. New "Type FA-6" switch is of steel, hydrogen-copper-brazed and exhausted to high vacuum through hollow steel operating stem. This stem passes into vacuum contact chamber through a thin steel end-wall whose flexibility permits necessary slight motion. Leading-in wires are sealed in tiny glass beads inside small Fernico alloy thimbles inserted through heavier opposite end-wall of chamber. (Fernico-glass seal is development of G-E Research Laboratory, provides sturdy gas-tight joint.) Metal construction permits use in locations subject to severe shock and vibration.

Fuses and Testers

Littelfuse Labs.

TATTELITES ("They Tell the Tale") is the name of a new line of safety neon potential fuses and testers designed to protect against and discharge dangerous excessive voltages (regular fuses protect against excessive currents). Principle and function same as in light-



ning arresters, only on smaller scale. Made to discharge potential ratings of 100, 250, 500, 1000, and 2000 volts; are glass enclosed, filled with rarefied neon; glow brightly when operated. Feature of the 500, 1000, and 2000 volt sizes is that discharge potential may be lowered about 40% by touching tube glass with hand.

Sensitive Galvanometers

G-M Laboratories, Inc.

THREE new additions to G-M line; two are ballistic galvanometers. Features include: (1) light source which may or may not be used as integral part of instrument; (2) coil lock minimizing suspension breakage while galvanometer is being moved about; (3) high-ratio worm drive for adjusting angular position of mirror; (4) leveling base housing light-source transformer. Full G-M line now includes five galvanometers, for "practically every need." Three have current sensitivities of 0.0005, 0.003 and 0.0025 microamp./mm. deflection at 1 m. scale distance; two have undamped ballistic sensitivities of 0.0015 and 0.015 microcoulombs/mm. at 1 m. The latter is particularly suitable for use as a fluxmeter. All are finished in black crystal enamel and white plate.

Totalizing Demand Meter

Westinghouse Elec. & Mfg. Co.

TYPE WA a.c. Totalizing Demand Meter is designed for use with one or more watthour meters equipped with the Type QD Contactors (see below). Intended primarily for use with a-c. watthour meters, but can be used with a combination of d-c. and a-c. watthour meters where it may be desired to totalize the demand on both d-c. and a-c. circuits. A-c. supply is necessary for the timing motor. Totalizing mechanism comprises demand pointer gearing and timing motor gearing, plus a notching relay and the timing motor. Demand pointer gearing, connected to ratchet shaft of notching relay, is therefore actuated and controlled by impulses from the watthour meter or meters equipped with QD contacts connected in series with this notching relay. Demand pointer, advanced by a pointer pusher driven by demand gearing, remains by friction at

the point of maximum demand until manually reset to zero. At end of each time interval, pointer pusher is returned to zero position, energy required for this being stored in a reset spring during time interval by timing motor. At end of time interval, reset mechanism is tripped by timing motor and pointer pusher is driven back to zero through a friction clutch.

Timing element consists of a 600 r.p.m. sub-synchronous motor. Notching relay or impulse motor, of quick-acting type (about 1/25 sec.), operates on 30 volts d.c. also obtained from the a-c. supply line through a resistor and a Rectox unit. In the WA meter, a resistor of approx. 3750 ohms is connected directly across the 120-volt a-c. supply source. Taps are taken off to provide 30 volts for the notching relay which, being connected in series with the QD contacts, makes it unnecessary to have a separate supply source for these. Maximum demand pointer of register shows totalized maximum demand over a predetermined time interval. Its gearing and the reset mechanism of the new meter are same as employed in Type DR demand register. Scale is 300° (100 divisions) and gearing is so arranged that 200 impulses will cause maximum demand pointer to advance from zero to full scale.

Transmitting Contactor

Westinghouse Elec. & Mfg. Co.

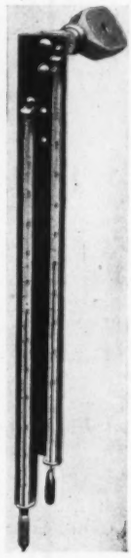
FOR transmitting impulses from one or more watthour meters to a suitable impulse-operated demand meter (such as Type WA). Quick-acting char-

acteristic of new "QD" contactor makes it possible to totalize demand on two or more circuits by connecting contact mechanisms of several watthour meters in series with operating coil of the quick-acting demand meter. It is necessary to arrange gearing and cams so that, for a given installation, impulse value in kw. will be the same for each contact device. Principle differs from that of ordinary demand contacts in that new QD contact has a quick-break feature which permits series connection of several contact devices without causing a loss of impulses due to their simultaneous occurrence (time required for operation being approx. 1/25 sec.). A shaft carrying two cams is driven from an extra pinion on the disk shaft of the watthour meter. Each cam operates a brush which carries a contact. A stationary brush carries a third contact. Stationary contact and one of movable contacts are connected in common to one side of impulse circuit. During cycle of operation, circuit is closed continuously except for an interval of 1/25 sec. in which contacts are opened to cause the demand impulse. Brushes and contacts are so arranged that when moving contacts are not lifted by cams, the three contacts are closed. When cams lift movable brushes, contacts on these two brushes remain closed, keeping impulse circuit closed. The brush carrying movable contact not connected in common with stationary contact, drops off cam an instant before other brush drops. This causes impulse circuit to be opened during interval required for one movable contact to drop away from other movable contact and make connection with stationary contact. An instant later, other brush drops off cam, bringing all three contacts back to the closed. This prevents circuit from being opened when cams again lift brushes.

Folding Sling Psychrometer

Precision Thermometer & Instru. Co.

CONSISTS of two etched-stem laboratory thermometers 10″ long. In "No. 426" the thermometers are graduated from 0° to 110° F. in ½° divisions; In "No. 428" the thermometers are of high precision laboratory grade graduated from 25° to 40° F., in 1/10° divisions. Mounted on a flanged aluminum plate. Upper ends of thermometers terminate in "mushroom heads" which engage slots in plate and "head-clamps" attached to plate by round-head machine screws: arrangement permits dismounting and replacing thermometers, obviating the necessity of returning instrument to factory for repairs. Aluminum grip of special design has a smooth long bearing swivel, and is pivoted against a spring snap in a stout yoke riveted to the aluminum plate. Aluminum carrying case, special design, consists of a rectangular seamless drawn tube drawn over special dies made especially for this instrument. Psychrometer fits case with a freely sliding telescope fit. Case is provided with provision for locking psychrometer in case. Overall length, 12″.



Timing Switch for Meter Testing

Electrical Facilities, Inc.

INTENDED primarily for use in testing of watthour meters, this device is also suitable for other electrical timing operations. The "Uni-Snap Test Switch" has uniform snap action when switching on or off, assuring operator of exact moment of starting and stopping. While contact is made and broken by rapid rotation of contact disk, device differs from ordinary rotary switch in that rotary motion is produced by depression of a push button in direction of axis of rotor rather than by customary turning of rotor by means of a switch handle. When push button is depressed through 3/16″, rapid rotation of contact disk is accompanied by simultaneous axial motion of disk which wipes contacts and resets mechanism for next switching operation. This makes it possible to switch on and off with the same finger and identical pressure, on one button. Switch case, combination of Bakelite and "soft tough rubber," is resilient and yet possesses internal rigidity for proper alignment of mechanism.

MANUFACTURERS' NEW LITERATURE

In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

B361 **Automatic Pump Controller.** 4-page bulletin describes controller to maintain water in an elevated tank or standpipe between maximum and minimum levels. Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

B362 **Tritrol Regulator.** Leaflet illustrates a regulator which automatically varies the time of starting heating system in morning and of shutting it down at night. Jas. P. Marsh Corp., 2073 Southport Ave., Chicago, Ill.

B363 **Tubing Specialties.** Leaflet describes small draw-bench for drawing tubing for hypodermic needles, radio cathode sleeves, capillary and Bourdon tubes for industrial control equipment, etc. Summerill Tubing Co., Bridgeport, Montgomery Co., Pa.

B364 **Surveying Instruments.** 104-page book (in English) describes the line of surveying instruments manufactured by F. W. Breithaupt & Sohn, Kassel, Germany.

B365 **General Radio Experimenter.** September-October, 1934, of this house organ contains an article entitled "Power Factor Measurements in Oil Analysis." General Radio Co., 30 State St., Cambridge A, Mass.

B366 **Carborundum Brand Products in Finishing Microscopic Metal Specimens.** Leaflet gives instructions on grinding and polishing of samples, specifying products to be used. Carborundum Co., Niagara Falls, N. Y.

B367 **Wide Angle Lenses.** Leaflet illustrates results obtained with B & L Wide Angle Lenses. Bausch & Lomb Optical Co., Rochester, N. Y.

B368 **Self-Calculating Resistance Charts.** Resistance values and associated data may be determined directly by means of a collection of self-calculating resistance charts issued by the engineering staff of Hardwick, Hindle, Inc., Newark, N. J. Charts give relations between resistance, voltage, current and power of any resistor or rheostat; are used by laying a straightedge on any two known values and reading the unknown on a third scale.

B369 **The Alloy Pot.** Vol. 2, No. 4 of this publication discusses the application of zinc die castings to the manufacture of a gasoline pump. New Jersey Zinc Co., 160 Front St., New York, N. Y.

B370 **Metered Boiler Regulation,** Bulletin M describes the Askania system of automatic control for steam boilers. H. A. Brassert & Co., 310 South Michigan Ave., Chicago, Ill.

B371 **The Ferrogram.** October issue of this house organ discusses the "Continuous Automatic Magnetic Inspection of Steel Bars, Tubing, Wire, etc." Ferrous Magnetic Corp., 110 Washington St., New York, N. Y.

B372 **Solving Industrial Crimes.** Form No. 1304 mentions a specific application of a recorder to saving in power costs. Esterline-Angus Co., Indianapolis, Ind.

B373 **Xacto Meters.** Mailing piece illustrating the complete Xacto line of liquid meters. S. F. Bowser & Co., Inc., Fort Wayne, Ind.

B374 **Barcol Motors.** Issue of October 8 describes three interesting applications of Barcol motors to special electrical instruments. Barber-Colman Co., Rockford, Ill.

B375 **Spray-Painting & Finishing Systems.** Catalog "DC" covers, in condensed form, complete spray-painting equipment. De Vilbiss Co., Toledo, Ohio.

B376 **Bakelite Review.** Vol. 6, No. 3 issue of this publication illustrates the application of Bakelite to several instruments. Bakelite Corp., 247 Park Ave., New York, N. Y.

B377 **Reflectometer and Color Comparator.** Circular 461 describes instrument for measuring the reflection coefficient of paint. Henry A. Gardner, Washington, D. C.

B378 **Microscope and Camera.** Mikro 500 e is a 26-page bulletin in English on the Zeiss Neophot for magnifications from 4 to 2000 x. Carl Zeiss, Inc., 485 Fifth Ave., New York, N. Y.

B379 **Ring Illuminator.** 20-page booklet in English, showing results obtained with the ring illuminator in the photography of opaque objects. E. Leitz, Inc., 60 East 10th St., New York, N. Y.

B380 **Photomicrographic Cameras.** Two leaflets describe three photomicrographic cameras for use with standard desk style microscopes. Spencer Lens Co., 19 Doat St., Buffalo, N. Y.

B381 **Electric Governor Controlled Motors.** Section 2040 illustrates several types of single phase, d.-c., electric governor-controlled motors. One application illustrated is the Kirby Timer, an instrument used in timing major airplane and athletic events. Bodine Electric Company, Chicago, Ill.

B382 **Phase Sequence Indicator.** Bulletin describes an instrument to eliminate the frequent losses due to wrong "phasing in" by utility company line crews. Electrical Facilities, Inc., 3712 San Pablo Ave., Oakland, Calif.

B383 **Meter Testing Equipment.** Bulletin covers a meter testing bench for watthour meters. Electrical Facilities, Inc., 3712 San Pablo Ave., Oakland, Calif.

B384 **Glossmeter.** Circular 456 describes an instrument which measures the gloss of various types of finishing materials. Henry A. Gardner, Washington, D. C.

B385 **Precision Multiplier.** Catalog 4210 describes and illustrates a 6-range multiplier for use with a milliammeter. Morrill & Morrill, 30 Church St., New York, N. Y.

B386 **Pressure Recording Instruments.** Bulletin 834 describes the three types of measuring elements: Sylphon type, Bourdon tube type and Piston type. Esterline-Angus Co., Indianapolis, Ind.

B387 **Minute Minder.** Direct mail piece describes a timer available in 2 styles: 60-minute dial and 15-minute dial. Walser Automatic Timer Co., Chrysler Bldg., New York, N. Y.

B388 **Vitameter A.** Publication No. 191/5 illustrates an apparatus for measuring the vitamin A content of cod and other fish liver oils and foodstuffs. Adam Hilger, Ltd., 98 Kings Road, Camden Road, London, England.

B389 **Industrial Measuring Instruments.** 40-page catalog Fe 140e, (in English) illustrates measuring instruments manufactured by Zeiss. George Scherr Co., 128 Lafayette St., New York, N. Y.

B390 **Dilatometer.** List Metallo B No. 7262 is a 40-page booklet entitled "Thermal analysis of metals by means of the automatically recording dilatometer." E. Leitz, Inc., 60 East 10th St., New York, N. Y.

B391 **Graphite Surfaces and Lubrication.** Technical Bulletin J220 discusses benefit of adding colloidal graphite to oils used for lubrication. Acheson Colloids Corp., Port Huron, Mich.

B392 **Industrial Cable.** 128-page Bulletin GEA-1838 describes and lists all standard types of insulated wire and cable. General Electric Co., Schenectady, N. Y.

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B394 **Hygrometers, Psychrometers, Meteorological Thermometers, Barometers, and Rain and Snow Gages.** 40-page Bulletin H gives description and prices of the following in addition to the above: hygroscopes, sling psychrometers, ventilated hygrometers, meteorological thermometers, Sixe's thermometers, self-registering thermometers, soil thermometers, indoor and outdoor thermometers, orchard and orchard alarm thermometers. Precision Thermometer & Instrument Co., Philadelphia, Pa.

B395 **Stirrer.** Bulletin 1202 covers a new laboratory stirrer, together with a complete line of stirrer accessories. American Instrument Co., 774 Girard St., N.W., Washington, D. C.

B396 **Microscope Record.** September 1934 issue contains the following articles: Microscopical Mineralogy; The Oedogoniales; The Non-silicious Basis of Diatom Structures; Dr. Henri van Heurck. W. Watson & Sons, Ltd., 313 High Holborn, London, W.C.1, England.

B397 **Cubicle Switchgear.** Bulletin GEA-1137B describes the indoor a.c. cubicle switchgear with manually or electrically operated breakers up to 15,000 volts and 2000 amperes. General Electric Co., Schenectady, N. Y.

B398 **Switches.** Bulletin GEA-1327A is on Indoor Disconnecting Switches with Silver Line-pressure Contacts. Bulletin GEA-1585A: High-voltage Magnetic Switches, Oil-immersed. General Electric Co., Schenectady, N. Y.

B399 **Profile Contour Projectors.** 28-page bulletin describes these projectors for inspection and measurement of contour forms. E. Leitz, Inc., 60 East 10th St., New York, N. Y.

B400 **Optical Instruments.** 60-page catalogue briefly describes all the optical instruments for laboratory and workshop in metal producing and metal working industries. E. Leitz, Inc., 60 East 10th St., New York, N. Y.

B401 **Smoot Regulators.** Catalog No. S-10 contains complete data covering the application, principle of operation and construction of Smoot regulators. 24 pages, excellently printed and bound. Smoot Engineering Corporation, 2240 Diversey Parkway, Chicago, Ill.

B402 **Plastics.** 26-page bulletin, "A Ready Reference for Plastics," is a compilation of data on pheno formaldehyde resins, laminated and cast; casein; cellulose acetates; hard rubber; shellac; and urea base molding compounds. This is an excellent reference book for all those who use such materials in molded shapes. Boonton Molding Company, Boonton, N. J.

B403 **Hydrometers.** "Blue Book Part 2" is an 8½x11" 16-page descriptive catalogue of standardized "Durac" hydrometers, thermo-hydrometers, thermometers and accessories, arranged by industries: refining, sugar, dyeing, tanning, distilling, etc. Also contains useful tables. H-B Instrument Co., 2516 N. Broad St., Philadelphia, Pa.

B404 **Relays.** "Weston Relays" is title of a new 12-page bulletin now being distributed by the Weston Electrical Instrument Corp., Newark, N. J. On its pages are grouped comprehensive lines of sensitive, toggle, polarized, power and time delay relays. The bulletin might well be termed a complete summary of over 30 years' experience in the development and manufacture of relays.

B405 **Recording and Controlling Instruments for Humidity and Drying Processes.** 32-page Bulletin 188, "A Complete Humidity Instrumentation." The following instruments are covered: relative humidity recorder, relative humidity and temperature recorder, relative humidity controller, close-coupled psychrometer, long distance psychrometer and the Kilnboy. Foxboro Co., Foxboro, Mass.

B406 **Heavy Duty Air Circuit Breakers.** 14-page Catalog No. 5 covers type HD air circuit breakers for 5 to 10,000 amps., 750 volts a.c., 600 volts d.c., giving complete details. Roller-Smith Co., 233 Broadway, New York, N. Y.

B407 **Photoelectric Cells.** 6-page folder gives electrical and mechanical data on Cetron Cells for use with instruments, controls and sound equipment. Continental Electric Co., St. Charles, Ill.

B408 **Ultraviolet Photomicrography.** 8-page folder discusses a simple and easy means of making photo-micrographs in the ultra violet. Specifications and prices of optics and other accessories are listed. Bausch & Lomb Optical Company, Rochester, N. Y.

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INSTRUMENTS BOOK SHELF

'f" [the pipe line flow factor]. By FORREST M. TOWL. Privately printed. New York, 1934. Cloth, 6x9¼ inches, 52 pages + extratextual charts.

For nearly half a century the name Towl has stood for brilliant engineering achievements in the transportation of fluids through pipes. It is for the next generation of pipe line engineers that the distinguished author has written this book and has had it handsomely printed and bound; but he assures us that copies will also be available (as long as the supply lasts) for any engineer interested in flow meters or pipe line work, provided such engineer submit evidence that he is familiar with the use of the flow formula and the Reynolds Number as it has been applied to that formula. The author's address is 26 Broadway, New York, N.Y.

The purpose of the book, as stated in Chapter I, is to consider the pipe line flow coefficient f in its relation to the steady flow of fluids through cylindrical pipes and to the Reynolds Number. In Chapter III, the author lays down certain propositions—as did Osborne Reynolds, but with more data than Reynolds had in his time and with more daring than Reynolds had to have: Today among the thousands of engineers and physicists who use the classic flow formulae in their daily work, there are few who dare hope for the emergence of simplified and unified formulae, applicable in the entire region of turbulent flow of liquids and gases. This book not only represents such a unification but it includes large charts whereon f is plotted against volume flowing—which the author reports being told "that this could not be done, that it was theoretically unsound." The propositions which the author lays down are six in number. The briefest is "Statement IV" and it also is the one which impressed itself most deeply in the reviewer's mind:

The number of cubic feet of water flowing per hour through a smooth pipe one foot in diameter is one-fourth the Reynolds Number for the corresponding f.

The author's unitary mathematical treatment may or may not be "sound." That depends on what the critics mean by "sound"—a subject which would take about three pages if one yielded to the temptation of writing a "highbrow" discussion. The reviewer will "go lowbrow" and state his conclusion in three words: Towl's stuff clicks.

The reason his formulae click is that his novel unitary scheme is based on the introduction of a factor for "pipe line specific viscosity" with water = 1. This coefficient ψ makes f applicable to all liquids and does away with the use of innumerable factors each for one liquid at one temperature—because *ex vi termini* (in Statement II) ψ is a measure of that characteristic property of a fluid which is due to its inherent density and viscosity.

Now then, in the practical application of this new scheme we have to introduce numerical values, or we have to go by the charts attached to the book—which of course had to be drawn from numerical values. *There* is where soundness or unsoundness would show up. And it is reasonable to assume that a man with fifty years' experience in pipe line work would not publish short-cut charts unless he knew from his records that all the values you take from these charts will prove correct when you have built your pumping station or pipe line or meter installation.

M. F. BEHAR (2.5)-**B-**

Tests on Volumetric Glassware. METROLOGY DEPARTMENT, NATIONAL PHYSICAL LABORATORY, Teddington, England, April 1934. Paper, 5½ x 8½ inches, 34 pages.

The booklet covers the regulations governing tests of volumetric glassware: flasks, pipettes, burettes, graduated pipettes, graduated cylinders, pyknometers, gas analysis apparatus, etc. No fundamental changes have been made from the preceding edition but several points have been dealt with in more detail.—RICHARD RIMBACH (12.1)-**B-**

Power Plant Testing. By J. A. MOYER, McGraw-Hill Book Co., New York, 1934, Fourth edition. Cloth, 6x9¼ inches, 614 pages. Price $5.00.

This book is divided into twenty-five chapters, of which the first nine deal with instruments and instrumentation, flow of fluids, fuel and gas calorimetry and flue gas analysis, the next fifteen deal with the subject-matter of the A.S.M.E. Test Codes, the Testing of Hoists, Belts and Friction Wheels, and the Testing of Lubricants. The final chapter gives a summary of laboratory tests, useful to the laboratory teacher.

Any writer dealing with the subject-matter outlined above is at once faced with the necessity of deciding to what extent the treatment shall lean upon the Test Codes and the Code Instruments and Apparatus of the A.S.M.E. It is true that some of the Test Codes are under revision, and that the Code on Instruments is not complete, but the binding together of what is published by the Society would in itself constitute a respectable reference book, for the practicing engineer, not for the student. The Codes assume, as they should, that they will be applied by trained engineers. Consequently in most cases formulas to be used are merely given in their final form, not generally derived. It is assumed that the book under discussion is primarily intended for the student. Hence, quite properly an attempt is made in the chapter on instruments to expand the mathematical treatment wherever necessity seemed to dictate, while the Test Codes, in the interest of keeping the book within reasonable size, are generally abridged. The result of the compromise is a work upon the merits of which one may well be of two minds. In the reviewer's opinion the treatment on instruments could well have been further expanded, although it must be admitted that the essentials are there and that the treatment is clear and the illustrations good. The charge made against some of the former editions, that some of the instruments described are old, does not lie against this edition, and in any case does not carry much weight, since the instrument field is constantly in flux. In detail, the present writer feels that, particularly in the chapter on Flow of Fluids, fuller treatment of some of the more frequently used methods of measuring fluids (Pitot tube, thin plate orifice and Venturi) would have been of benefit, particularly with reference to the variation of coefficients of discharge with varying conditions of flow. In the chapter on Calorimetry it is stated (page 241) that the steady flow calorimeter gives the *higher* heat value, while on page 242 this is properly contradicted and a good discussion given on the meaning of the terms *higher* and *lower* value. It is suggested that the heat value computed as outlined on page 241 be called the *calorimeter* heat value. The reviewer is surprised that, as far as he is able to discover throughout the chapter on Calorific Value of Fuels, no reference is made to the revised figures for the calorific values of Carbon and of Hydrogen, published in the International Critical Tables about 1931. These values are given on page 251 of the book as 146,000 B.t.u. and 62,000 B.t.u. respectively, while the revised figures are 14,158 B.t.u. and 61,060 B.t.u. With regard to Carbon this constitutes a difference of about 3%, certainly enough to cause any writer on this subject to make a critical examination of the sources.

As stated, the latter half of the volume deals with the Test Codes in abridged form. The curtailment has been wisely done and the result is quite satisfactory for student use. The writer of the book has recognized certain "opacities" in the Codes and has elucidated some of these places. This refers particularly to Chapter XIV which deals exclusively with methods for correcting turbine and engine test results to standard conditions, and by the use of practical examples helps to make clear the Code provisions.

Of course, where guarantee tests are involved, recourse will in the last analysis have to be had to the Codes as published by the A.S.M.E. But for student use, requiring a drastic condensation of a world of material in a very large field, if the book is to be kept within reasonable limits, the work must be considered satisfactory and a job well done.—H. DIEDERICHS (1.2)-**B-**

The Construction of Manually Operated Scales (Die Konstruktion der von Hand bedienten Waagen). by DR. M. RAUDNITZ, Bernh. Friedr. Voigt, Leipzig 1934. Paper, 8½x11¾ inches, first section 40 pages, price (each section) 3.75 R.M.

The author states that this work is a complete revision and modernization of the German scale classic "Die Konstruktion der Waage" by Brauer-Lawaczeck. This first section comprises six chapters which discuss the underlying theories to be observed in the construction of weight determining devices. Equilibrium, sensitiveness, period of oscillation, the effect of out of level condition of a weighing machine and many other subjects are ably reviewed. If the succeeding sections are equal to the one published, the work should find a place in the library of every engineer, even though he is not directly interested in the construction of scales and/or weighing instruments.

CARL J. ZINKE (11)-**B-**

Thermionic Emission. By ARNOLD L. REIMANN, John L. Wiley and Sons, New York, 1934. Cloth, 5¾x8¾ inches, 324 pages. Price $5.50.

Written by a member of the research staff of the (British) General Electric Co., Ltd., this book brings up to date under one cover the complete story of thermionic action. Its scope is limited to cathode emission effects only, and the viewpoint is that of the specialist in electronic phenomena—or of the research physicist. Since many modern technical developments have been based on thermionic emission this book may also prove of interest to those in that field whose efforts are now limited by certain tube deficiencies in such matters as constancy, life, and tube noises.

The author has included all theories that have been advanced on this subject since the earlier work of Richardson, together with an analysis of each. Many of the experimental data are included. Nearly all of the book is a review of published literature, although some original data hitherto unpublished are included. An extensive reference bibliography supports each chapter.

RALPH R. BATCHER (5.4)-**B-**

Power Loss Check Chart and **How 114 Plants Made Power Savings.** By the Editors of *Factory Management and Maintenance* and DAVID MOFFAT MYERS and N. ARTSAY. McGraw-Hill Publishing Co. New York, 1934. Wall chart, 39 x 32 inches.

One side of the chart contains well-ordered and illustrated information (applicable to any power plant and even to purchased power). On the reverse side are printed 114 short stories of power savings—many of these savings being due to the proper use of instruments and meters. Subscribers to *Factory Management and Maintenance* received this chart with the October issue. There may be a few left by the time this review appears in print.

M. F. BEHAR (1.2)-**B-**

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Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.

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Taylor Instrument Cos.

HYGROMETERS
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Foxboro Co.
Taylor Instrument Cos.

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INDICATORS—See Gages

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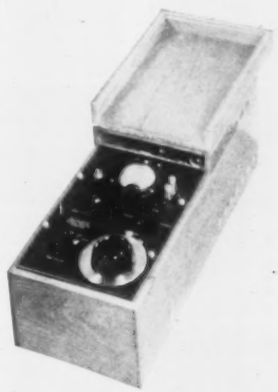

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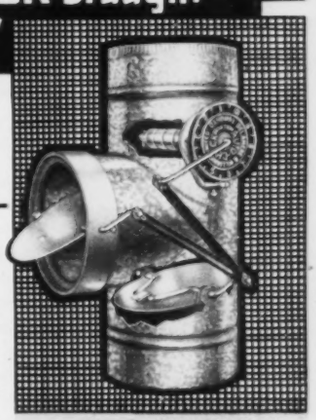

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